

**Kaufman -
Trading
Systems &
Methods -**

Chap23l

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23 Risk Control

A trading system alone will not assure success without proper risk control beginning with each trade and continuing until a portfolio of different trading methods is created. Systems have losing streaks that will ruin any investor with inadequate resources and poor timing; a speculator must decide the initial capitalization, the markets to trade, and when to increase or decrease leverage. There are risks that can be controlled or reduced, called systematic risk, and another called market risk, that can take the form of a price shock and can never be eliminated.

This chapter tries to cover a broad range of topics relating to risk, including individual trade risk, leverage, portfolio diversification and allocation, price shocks, and catastrophic risk. It is not possible to say that one is more important than another. In a specific situation, any one of the areas discussed may be the answer to preventing substantial loss. The first part of this chapter discusses capitalization and shows why many traders will be successful for months and then lose everything in only a few days. It will explain the choices in leveraging and offer alternatives of less risk. The last section analyzes when a system is performing properly and when it is not living up to its expectations.

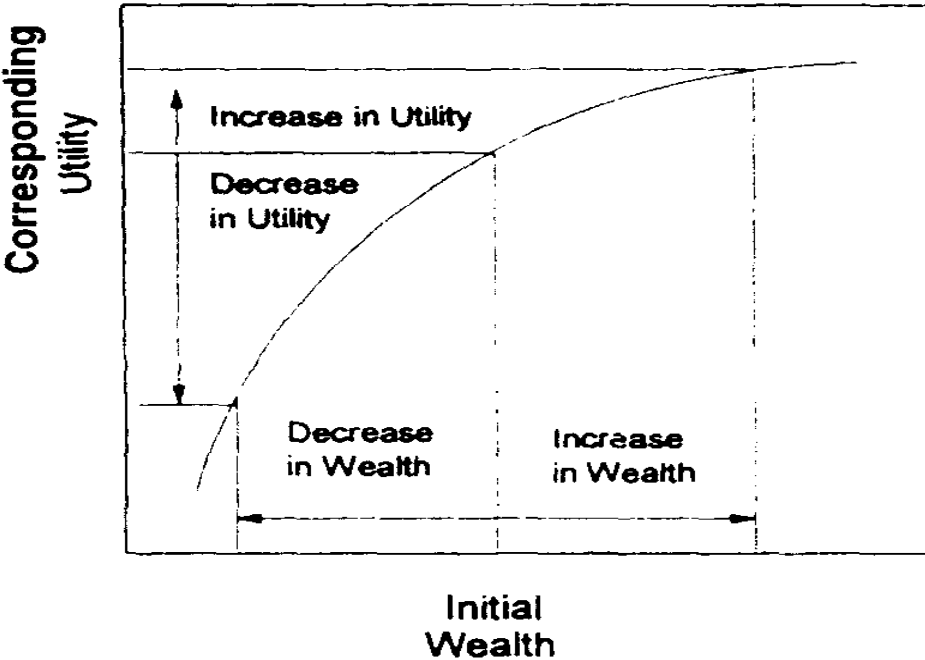
Risk control begins with a trading philosophy the most common is called conservation of capital. It is the assurance that the investor has been given the most opportunities for success, which usually translates into keeping losses small. This is often accomplished by allowing only small losses per trade or using a trendfollowing system. Once a trend position is established, it is held as long as prices continue in the direction of the position; it is closed out when the trend changes. The resulting performance profile is one of more frequent small losses and fewer large profits.

RISK AVERSION

Daniel Bernoulli, a famous mathematician, proposed a theory of utility in 1738 that distinguished between price and value, where price is equal for everyone but value (utility) depends on the individual making the estimate and their circumstances.

Bernoulli's approach defined a concept of diminishing marginal utility, shown in Figure 23.1, which indicates that as wealth becomes greater, then the preference for more wealth diminishes. In the lower left part of the chart, where the investor has a small net worth, the likelihood of accepting risk is much higher, although the magnitude of the risk is still small. When risk becomes greater, even proportional to return, all investors become cautious. Bernoulli's graph shows the curve beginning at zero and moving up and to the right in a perfect 1/4 circle, ending horizontally, where risk is no longer attractive. This implies that people are risk averse. Most people are not interested in an even chance of gaining or losing an equal amount. Other theories that have been proposed are that the market maximizes the amount of money lost, and the market maximizes the number of losing participants. All of these concepts appear to be true and are very significant in developing an understanding of how the market functions.

FIGURE 231 Changes in utility versus changes in wealth.



Source: Peter Bernstein, The Portable MBA in Investment 1995, p. 38. @ 1995 Peter Bernstein.
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Risk Preference

The Bernoulli theory of utility is general, but each investor has their own unique objectives and attitudes toward risk. Some of the participants in futures markets would like to keep risks low and returns steady; others would like to risk all of their capital for a chance at the "big move." This trait is called the investor's risk preference. The risk preference or utility of an investor for a specific venture (in this case a trade) can be found by adding the expected value of the investor's utilities or preferences for the various outcomes of that event,

$$P = w_1p_1 + w_2p_2 + \cdots + w_np_n, \quad \text{wh}$$

where there are n possible outcomes. The weighting factors may be the results of personal bias or may be the calculated probabilities of each outcome. For example, a gold trade has a likely profit of \$4,000, with a risk of \$1,500. Adjust the reward values by dividing by 1,000. If the probability of success is 60%, the total utility of the trade is:

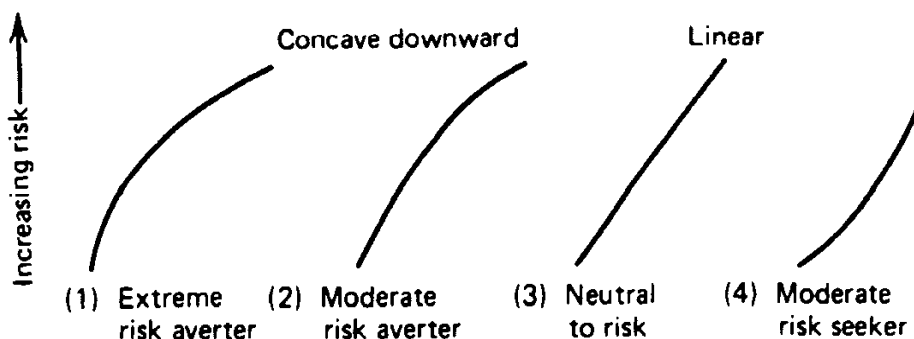
$$P(\text{trade}) = 0.60 \times 4 + 0.40 \times (-1.5)$$

If the probability of success were increased, the utility P would increase linearly. But investors do not feel the same about different rewards. Given a scale of 0 to 100 (negative to positive reaction), an investor may rank the 60% chance of a \$4,000 profit and a 40% chance of a \$1,500 loss as a 65. If the reward is increased to \$8,000 while the risk remains at \$1,500, the investor might raise the preference of the trade to 80, although the utility would be 4.2, more than twice as large.

The various patterns of a curve drawn through the computed utilities represent the risk preference of the individual. Figure 232 shows the curve formations progressing from extreme risk aversion to extreme risk seeking. As the risk increases in (1), the trader is less likely to participate in the trade; in (3), there is equal chance of taking the trade at all risk levels; and in (5), the trader is more likely to enter a trade that has higher risk.

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FIGURE 232 Investor utility curves.



Source: R.J. Teweles, C.V. Harlow, and H.L. Stone, *The Con* (McGraw-Hill, New York, 1974, p. 133). © 1974. Reprinted

Common Sense

Risk control is as much an issue of common sense as it is complex rules and mathematics. Most of the chapter that follows shows how various measurements, diversification, and leveraging techniques can reduce risk.' however, successful traders have applied common sense, without complex formulas, for a long time. Some of these principles are:

1. Don't risk very much of your total capital on any one trade. The total risked should allow you to comfortably survive more losses than you would normally expect.
2. With whatever method you use, determine the maximum loss for the current trade in advance. Many floor traders believe that their survival is the result of being the first to exit a trade. ("I didn't pay to get in, but where do I pay to get out?")

3. Exiting a trade is more difficult than entering because the timing is not always yours. Exiting quickly is often safer than being clever.
4. Stay with your trading philosophy. If you are a trend follower, then keep losses small and let profits run. You can't be a trend follower by taking many small losses and a few small profits.
5. Every system has a trading profile. Be sure that profile is agreeable to you.
6. Plan for contingencies. Not everything goes as planned, and you must be prepared for infrequent, but important exceptions.

LIQUIDITY

The realities of trading are directly related to the liquidity of the market. Even though liquidity can have more than one meaning, lack of liquidity has only one trading result: poor execution. A liquid market does not necessarily mean good fills, but an illiquid market assures bad ones. Two types of illiquidity are most often encountered in the markets:

1. Fastmoving markets, in which there are mostly buyers or sellers, and few traders are willing to take the other side of the position.
2. Inactive markets, usually in the deferred months in which there is less interest in either hedging or speculating.

The fast market is the result of a supplydemand imbalance, or perceived imbalance, where everyone is in agreement on the direction the market should move. The few hedgers and traders willing to take a position do little to offset the vast number of orders that flood the floor, pushing the price in the direction of the trend. In the inactive market, a premium must be paid to attract another trader to take the opposite trade. This will only succeed in

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RISK CONTROL

an inactive market when the bid or offered price clearly appears to give the other trader a guaranteed shortterm profit.

The illiquidity of a market produces the most important execution cost, often greater than a sizable commission and sometimes unreasonably large. Ginter and Richie² have described this as a function of the order size, volume, and the speed of the market, in a single formula:

$$C = K \times \frac{Q \times V}{L_t \times L_m}$$

where C = cost of execution due to liquidity

Q = size of the order entered

V = volatility of the market

L_t = volume of the market (all deliveries)

L_m = volume of the specific option (delivery month)

K = constant factor

The volatility V might be the daily range (high minus low), or a factor of the standard deviation of the range. This would provide a measure of how much volume would move the market a specified number of points. The total volume (liquidity) L_t is important because it implies liquidity due to interdelivery spreading. Volume also serves as a measurement of the general interest in the product. More active trading in other contract months opens the possibility for trading in all months given the right

circumstances.

The constant factor K will vary according to the nature of the order being placed and the current direction of the price with regard to that order. If prices are moving higher and a buy order is placed, K will be large; if prices are moving higher and a sell order is placed, K will be smaller. The investor can see that trading overhead, including both commissions and other execution costs, will have considerably greater impact on systems that trade more often, have smaller average profits, and trade in the direction of the trend. Given a choice between systems of equal gross profits, the investor should favor the method of fewest trades in the most liquid markets.

CAPITAL

Success does not depend on having enough capital, but in using it properly.

Dixon G. Warts

Every type of system has its own profitandloss cycle, depending on what price patterns or behavior it is measuring. A simple moving average will be profitable in a trending market and will lose in a nontrending one., a system that operates within a trading range will profit from nontrending situations. It has been estimated that prices spend 70% to 80% of their total time in a nontrending movement; therefore, when using a trendfollowing system, it is likely that trading will begin in a nontrending period. Because the risk of the system during a sustained trendless market may be unknown, it is best to start small. Find the minimum amount that can be used to follow the system in a representative manner. During the startup period, it is best to profit on 10% or 20% of capital than lose on 100%. Always begin slowlyactual trading performance is rarely as good as expected.

Establish the maximum margin based on the experiences of nontrending markets if uncertain, keep the total margin well under 50% of available capital. The following sections review ways of increasing margin and compounding profits.

Diversification reduces both risk and reward; done properly, the risk is reduced more than the reward. Using a welldistributed portfolio for a system whose risks are known, a

' G. Ginter and J. Richie, "Data Errors and Price Distortions," in *Technical Analysis in Commodities*, Perry J. Kaufman (ed.) (John Wiley & Sons, New York, 1980).

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larger portion of the total capital can be allocated to margin. Advantages of statistics become apparent in the netting out of profits and losses daily; the majority of trades will move in a favorable direction a majority of the time. The volatility of a portfolio will be dampened by this netting effect; a trade with a slow upward trend and a distant stoploss will be offset by a slow downward trending position in another commodity.

An undercapitalized account cannot be traded safely by selecting a system with a favorable riskreward profile. Because there is very little staying power, the trader must accept the fact that there is a small chance of success. There are two choices, based on the personality of the trader:

- 1 . Try for the maximum profit possible on a single trade with the capital available. If it loses, trading is halted. If it profits, there may be enough capital for a diversified approach.

2. Take a lowrisk approach, which allows the most losses for the given capital. This increases the time in the market, with comparably reduced profits. It is necessary to have an unusually long run of small profits to reach a point of success.

There are two important rules in managing an account: (1) Don't meet margin calls, which implies that a margin call represents an objective identification of a bad trade, or a system that is not meeting expectations. A margin call is a time to review trading performance. (2) Liquidate your worst position when lightening up. The profitable trades have proved that they are trending or performing properly; the losing ones have proved they are not. Stay with the good positions and liquidate the worst.

The management of capital is especially important at the beginning stages of trading, although it continually affects results. At some point, every trader wants to compound profits a system that is profitable can be more profitable. This philosophy most often leads to disastrous results. The next sections present methods for measuring risk, followed by a traditional and a conservative approach to compounding and increasing leverage.

MEASURING RISK

An important part of both system development and money management is the recognition, measurement, and ultimately, the limiting of risk. Broadly speaking, money management is the art of limiting the risk of a portfolio while maximizing its return. To perform these tasks, it is first necessary to select, or develop, profitable trading strategies to be used for each commodity. It is the results of these strategies, both simulated and real, that will be used to structure a riskcontrolled trading program (see the discussion of "System Trade Offs" in Chapter 22).

Selecting a Trading Model

A trading model is a set of rules and formulas that, when applied to a price series, yields trading signals. These signals might be as simple as buy and sell Market on Close or complex contingent orders involving multiple delivery months and markets. To simulate results, the model must be well defined; that is, all the rules must be logically stated and programmable. Interpretive methods, such as many charting techniques, cannot be simulated; they depend on patterns that cannot be defined in advance. The use of actual trading results for later analysis is always preferable and is not limited to computerized systems.

Suppose there is a choice of systems to trade, and the daily equity of each is available. If only one can be selected, which should it be? There are some characteristics of performance that are universal: 3

3 Norm Strahm, "Preference Space Evaluation of Trading System Performance," in *Handbook of Futures Markets*, Perry J. Kaufman (ed.) (John Wiley & Sons, New York, 1984).

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1. Larger profits are better than smaller profits.
 2. Small, shortterm fluctuations are better than large, shortterm fluctuations.
 3. Upward equity surges (profits) are better than downward surges (losses).
- Naive Performance Criteria

The use of a single piece of information is not sufficient to satisfy the basic criteria stated previously. The system with the ~mum profit is not necessarily a good choice. There might have been a run of losses greater

than the investment before profitability was achieved. Similarly, the risk alone is not sensible. The system with the smallest risk is one that never trades. A valid performance measurement technique must include a comparison of risk and reward.

The Sharpe Ratio

The classic measurement of performance is the Sharpe Ratio (SR), expressed as

$$SR = \frac{E - I}{\sigma}$$

where E is the expected return, I is the riskfree interest rate, and σ is the standard deviation, or fluctuation, of the periodic returns (for example, the yearly returns). For practical purposes, E should be an annualized rate of return in percent, if you expect that return to continue, and I is often omitted. The inclusion of I is important when a large part of the performance is a contribution of interest on the investment, or when the equity streams being compared are inconsistent in their use of interest income. The standard deviation of the equity is a standard way of measuring risk.

The Sharpe Ratio satisfies the first criterion, that all else being equal, higher profits are better. It does not satisfy either of the other requirements, because it cannot distinguish between:

1. Consecutive small losses (System B) and alternating small losses (System A)
2. Large surges of profits and large losses (Figure 233)

Clearly, System A is best in both cases.

Average Maximum Retracement

Schwager⁴ has presented a comprehensive study of evaluation techniques. Although each method may emphasize a particular equity trait, he seems to favor the average maximum retracement (AMR). This method answers the question: "For each day, what would be the retracement if one had started trading the system on the worst possible trade entry date?" The AMR is the average of the daily maximum retracement values.

$$AMR = \frac{1}{N} \sum_{i=1}^N POS(MCE_i - TE_i)$$

where

$$POS(X) = \begin{cases} x & \text{if } x > 0 \\ 0 & \text{if } x < 0 \end{cases}$$

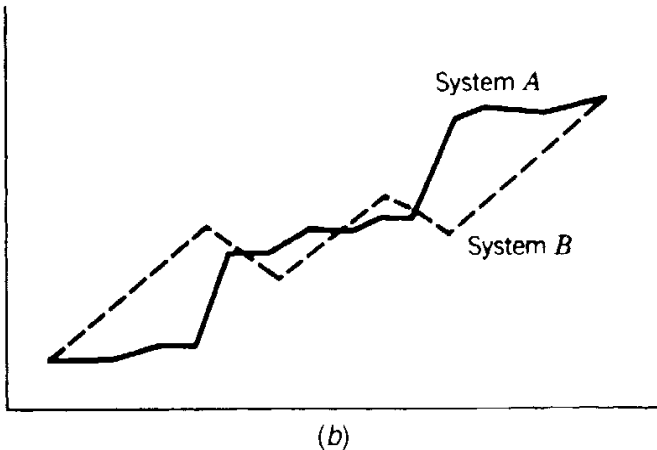
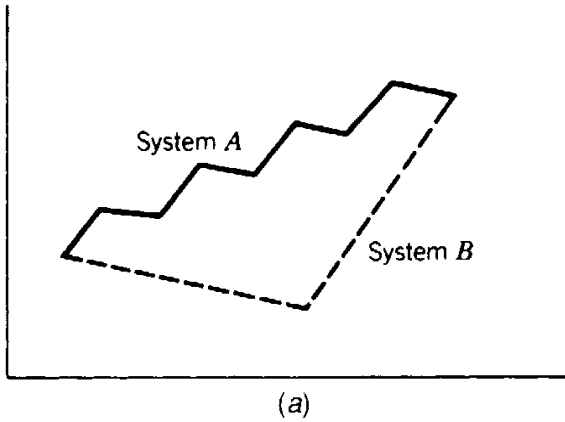
and MCE = closedout equity (realized profits) on any trade entry date prior to i

TE_i = total equity on day i

N = total number of days of equity data

⁴ jack D. Schwager, *A Complete Guide to the Futures Markets* (john Wiley & Sons, New York, 1984).

FIGURE 233 Two cases in which the Sharpe Ratio fails. (a) The order in which profits and losses occur. (b) Surges in profits versus evenly distributed losses.



When $TE_i > MCE$, all traders will have a profit on day i , regardless of when they began. Schwager suggests that a much simpler computation would use only the low total equity day of each month; it would give a rough but good approximation.

Largest Loss

Measurements such as Schwager's AMR, and even the basic standard deviation, are good techniques for comparing the longterm performance of one system against another; they lack a certain reality of simply looking at the largest loss seen over the test periods. John Sweeney calls this the maximum adverse excursion,' claiming that traders should minimize the size of their largest loss.

Consider the standard deviation of equity changes, showing that in

any month there is a 68% chance that your returns will be between 15% and 5% (a mean of 5% and a standard deviation of 10%). There is only a 2.5% chance that you will lose more than 15% in 1 month (2 standard deviations); therefore, there is a 50% chance you will lose that 15% in 1 of the first 20 months (20 ÷ 2.5). Yet probability shows that you should lose more, if you keep trading, or less if you stop sooner.

The largest trading historic loss, called the maximum drawdown, is a practical alternative. It simply states that the trading program did, for example, lose 15% during 1 month of a 3year test. While it is possible, and even likely, that the program will have a larger loss in the future, you must be prepared for a 15% loss in a single month.

John Sweeney, Maximum Adverse Excursions for Stops, Technical Analysis of Stocks & Commodities (April 1987).

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Potential Risk

The measurement of risk may include other safety factors. Once a large loss has occurred, it is likely that a larger one may follow. It is unreasonable to think that all future losses will be smaller than the maximum already experienced. This potential for loss can be expressed as a probability by calculating the standard deviation of all equity drops, measured from lows to previous high equity points, and creating an equity drop ratio (EDR):

$$EDR = \frac{E}{\sigma(ED)} = E/@stdev(ED)$$

where E is the annualized return (equity), and o(ED) is the standard deviation of the equity drops. Although this is not far from Schwager's approach, it satisfies all three of the original criteria: higher profits are favored, the order of profits and losses will result in larger and smaller net equity drops, and large gains are not penalized because only the drops are used to measure risk.

The conservative investors may want to include some additional simple considerations of potential risk. All else being equal, systems with greater risk will be:

1. Those tested with samples that are too small
2. Those that have not shown any (or few) equity drops
3. Those that concentrate on fewer product groups (not properly diversified)
4. Those that compound positions

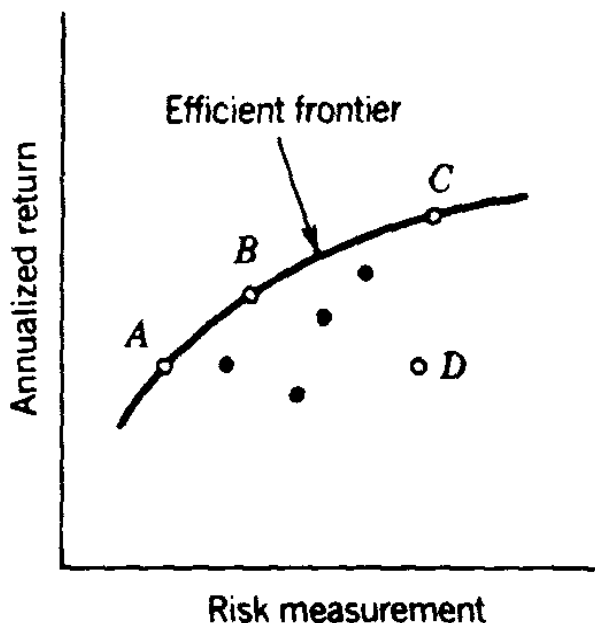
Efficient Frontier

It is always helpful to visualize the relative risk of how one system performs with respect to others. A plot of each system using its return and risk as coordinates will appear as in Figure 234.

Clearly, the best system would be the one that had the highest returns (C) if all of them had the same risk; or A, the one with the lowest risk, if it also had the highest profit. The three systems, A, B, and C, are

similar because they have the highest returns for their level of risk. However, each used a different degree of leverage, or reserves, and therefore had close to the same profit to risk ratio but in different magnitudes. The choice between systems A, B, and C is a personal preference discussed earlier in this chapter. Theoretically, the best choice is found by drawing a straight line from the riskfree rate of return (on the left scale) to the tangent point on the efficient frontier. This selection avoids the combinations in which risk increases more quickly than reward.

FIGURE 234 Efficient frontier.



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Risk Characteristics of Systems

The selection of a type of trading approach implies the type of risk you are willing to take on each trade. The difference between trend and countertrend systems was discussed in the section System TradeOffs in Chapter 22 ("Practical Considerations"). In general, a trend system has many smaller losses and fewer larger profits; a countertrend system has the opposite, many smaller profits and fewer larger losses. This is similar to the choices available with gambling strategies.

Even among trending systems there are enormous differences in trading risk. A typical moving average system, which qualifies under conservation of capital, keeps individual trade losses small compared with individual profits, but may have a series of losses that add up to one very large continuous loss. In addition, trend systems fail when they encounter a sideways period, and frequently reverse from long to short and back again until prices finally pick a direction. Tests show that you cannot reduce the number of trend trades below a threshold level, even if you make the trend

period very long. it always gets caught in a sideways price pattern that generates a series of small losses.

A breakout system, the other very popular trending technique, exchanges a much larger risk for much greater reliability than the moving average or exponential smoothing. When a new long position is entered based on a new high price for a specific time period, the risk is defined as the price needed to make a new low for the same period. Therefore, the trade risk at the time of entry is the difference between the high and low for the period,

$$\text{traderisk} = \text{@highest(close, period)} - \text{@lowest(close, period)}$$

If the highest high and lowest low are used, the risk can be much greater.

The advantage of the moving average or smoothing method is that individual losses are small. Using the breakout approach, the advantage is that the method does not demand as much of price movement; that is, prices may be very erratic, and take as long as needed to move to a new level, as long as they do not make a new low. It seems illogical that, if prices had given a buy signal by moving to new high levels because something fundamental was affecting the market, prices could turn around and make a new low. That would indicate that the reason behind this move has disappeared.

RiskAdjusted Returns

The decision whether to choose one trading approach with higher returns and higher risk, or another with smaller returns and lower risk can be resolved by converting performance to an annualized, riskadjusted return. Using any method for measuring risk a standard deviation of monthly equity changes, average maximum retracement, or even largest drawdown divide the annualized rate of return by the risk to get the riskadjusted rate of return. The highest value is the better choice.

Time to Recovery

A trading program that recovers quickly from losses is more desirable than a program that lingers at its lowest level of loss. The fact that the first program recovers quickly does not change its level of risk, only its practical appeal.

How Much Bigger Could the Risk Really Be?

Many of the risk measurements described in this section attempt to express the probability of a future loss. Within reason, many of them succeed. An investor must distinguish between the calculated probability and the effects of a real loss. If there was only a 1% chance of a 50% loss in a single month, then by the 50th month there would have been a 50% chance of a 50% loss. There is also a large error factor in most of these calculations because the amount of data used to find the statistics was too small. If 100 cases were used

there is still a 10% chance of error in the results. The value of the measurement is also dependent upon the period in the market that was used to create these values; the risk in crude oil was exceptionally high during the Gulf War. If that period is not included, the risk of trading crude oil might seem very low.

LEVERAGE

The consequences of leverage are readily seen in a risk/reward analysis, but it also plays a crucial role in the trading strategy itself. Futures markets offer exceptionally high leverage opportunity, and most traders and analysts act as though they are obligated to take advantage of the maximum allowable. Without leverage, futures prices show no more risk than stocks.

Consider the case of an investor with the substantial sum of \$50,000 allocated to futures trading. If the price of soybeans is \$6.00 per bushel and silver is \$7.00 per ounce, a 5,000bushel contract of soybeans is worth \$30,000 and a 5,000ounce contract of silver is valued at \$35,000. With no leverage, the investor could only purchase one contract with the certainty of being able to hold that contract as long as necessary to achieve a profit. Let us assume that, because of fundamental reasons, the investor believes that soybean prices wig move to \$8 per bushel and silver to \$11 per ounce within the next 6 months. The nonannualized gross return on investment will be 33% for soybeans and 57% for silver, equivalent to a 20% and 40% return on \$50,000, respectively. With no leverage and not enough money to invest in both, the choice must be silver, which has the highest return; in neither case could their be any risk of ruin. in both cases there would be surplus capital.

But 100% capitalization is hardly necessary. Even the most conservative investor would agree that the price of either commodity would not drop to 30% of the current value; therefore, there is no significant risk in capitalizing 70%, rather than 100%, of the contract values. By reducing the individual capitalizations, the investor can then purchase both silver and soybeans, thus adding diversification and a much higher return on the available investment. Table 231 shows that 30% leverage would increase the return on investment From 40% to 60%, in addition to the way in which the investment could be allocated, given different levels of capitalization.

As the capitalization is lowered and the leverage increased, both risk and return get rapidly larger. In Table 231, there are certain levels which are more significant than others:

TABLE 231 Varying the Leverage of an Investment

Leverage (%)	Soybeans			Silver		
	Qty	Needed (\$)	Profit (\$)	Qty	Needed (\$)	Profit (\$)
0	0	30,000		1	35,000	20,000
10	0	27,000		1	31,500	20,000
20	0	24,000		1	28,000	20,000
30	1	21,000	10,000	1	24,500	20,000
40	1	18,000	10,000	1	21,000	20,000
50	1	15,000	10,000	2	17,500	40,000
60	1	12,000	10,000	2	14,000	40,000
70	2	9,000	20,000	3	10,500	60,000
80	3	6,000	30,000	4	7,000	80,000
90	7	3,000	70,000	8	3,500	160,000
95	15	1,500	150,000	15	1,750	300,000

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30% leverage, the point at which there is added diversification, an increase in return, and a negligible increase in risk.

90% leverage, equivalent to exchange minimum margin levels.' It allows wellcapitalized traders to have margins averaging about 10% of the contract value.

95% leverage, equivalent to the margin level given to hedgers and spreaders, based on owning the physical product as offsetting risk.

At 90% leverage, the investor is required to use \$49,000 for margin. The positions may be maintained without an additional investment as long as the account does not show a loss in excess of \$12,2507 (with a total of 30 contracts, i.e., equivalent to a loss of \$408 per contract, or 80 per ounce of silver and 8c per bushel of soybeans). Because the daily trading range of both commodities exceeds that value, it is very possible to have a margin call on the first day the position is established. It is not possible for an investor to hold this position for long.

Reserves

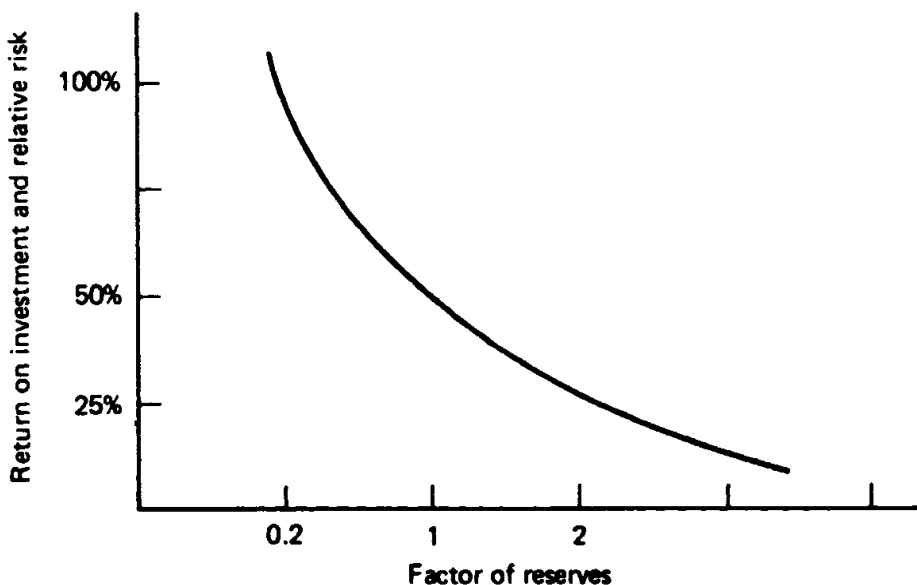
Most professional money managers use reserves to reduce the leverage and risk, thereby increasing their staying power. The size of the reserves usually averages about 60% of the capital; however, ranges of 10% to 80% have been known. The use of a 50% reserve effectively halves the returns and the risk (Figure 235).

Looking again at Table 231, there is now only \$25,000 of capital available for margin. If exchange minimum margin rates are used, there is 90% leverage available; this means each contract of soybeans requires a \$3,000 deposit and each contract of silver \$3,500. The 80% leverage line, with onehalf the margin shown, would require a total margin commitment of \$23,000, slightly under our limits. The net effect of 90% leverage on onehalf the total investment is the same as 45% leverage. Returns are:

6 In futures trading, initial margin is the minimum amount required on deposit when the position is entered.

'Maintenance margin is the level of capitalization that must be maintained in the account. Losses that reduce equity to below 75% (the current maintenance margin level) of the initial margin level require the investor to reestablish the capitalization to the full initial level.

FIGURE235 Varying reserves, assuming a 50% return on \$50,000 (with standard reserves= t).



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3 contracts of soybeans × \$10,000 profit =	\$30,000
4 contracts of silver × \$20,000 profit =	\$80,000
Total profit	\$110,000
Net return on investment	18%

DIVERSIFICATION

Diversification means spreading risk; it is the well-established way of lowering systematic risk, and every investor is well advised to diversify'. For the purposes of risk reduction, it is necessary to distinguish between systematic risk, which can be reduced by diversification, and market risk, which cannot be eliminated. The benefits of diversification are greatest when the markets traded are very different and the methods of making decisions are also unrelated. Typical investment portfolios contain a variety of fixed income, equities, real estate, art, as well as different investment philosophies, all intended to provide different rates of return with different patterns and not suffer losses all at the same time. Unfortunately, this is not always the case. Market risk, including catastrophic risk, is not predictable, and can surprise even the best investors. Avoiding market risk is the subject

of this and other sections in this chapter.

Practical diversification can be implemented using a broad selection of markets within a single tactical system, a selection of different trading strategies for one product, or a combination of multiple systems and products. The objectives of diversification are:

1. Lower daily risk due to the offsetting of losses in some markets and systems with profits in others.
2. Insure participation in major moves by continuously trading those markets in various groups that are likely to reflect fundamental changes. This avoids the need to identify which market will perform the best.
3. Offset unexpected losses caused by a system failing to perform in the current market, or a single trade that generates a large loss. It may be only had luck that one System gave a short signal in coffee the day before the freeze that moved prices limitup for 21 days, but another system might have given an offsetting buy signal
4. Reduce cynosure in any one market or related group by, having funds distributed over many groups. If there are 10 unique asset classes, then an equal allocation only risks onetenth of the portfolio. The more groups, the less the risk.

Diversification is accomplished by applying as many of the following techniques as possible:

1. Selecting individual markets from different groups. Trying to trade those products with as little interrelationship (low covariance or correlation, discussed in Chapter 3, "Regression") as possible. Traditionally, futures markets have been categorized into sectors of interest rates, currencies, index, grains, livestock, metals (industrial and precious), foods, and miscellaneous. The last group accounts for fibers, woods, oil, and other products with little relationship to other markets.

There is a larger category called financials, which encompasses interest rates, currencies, and index markets. While these sectors tend to move on their own most days, they are known to have very sympathetic, correlated reactions to unexpected economic news. This overriding similarity must be considered when allocating assets within a portfolio.

Even without the close economic ties shown by the financials, there is considerable interaction between all of these groups. Without special news, agricultural markets have little to do with metals and each moves according to their own funda

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mentals; however, a radical change in the value of the U.S. dollar or interest rates could move all prices in the same direction. For example, rising interest rates are bad for commodities that must be stored, because it increases those costs. In sum, investors will sell gold and farmers will sell soybeans rather than pay a larger carrying charge.

Slow changes in the value of the U.S. dollar will affect export markets:

changes in interest rates will directly impact the stock index. A crisis in the potato market, however, has little effect on other areas of the economy. When selecting those markets to be used in a diversified portfolio, it is necessary to check the historical similarity of equity patterns as well as consider the major forces that currently drive the market both historic and predictive sides of the problem. When properly selected, diversification will reduce risk, as shown in Figure 236.

2. Multiple systems. Using more than one system will reduce risk, provided the systems are not similar. Techniques may appear different and yet be highly correlated. A moving average system, ARIMA model, and pointandfigure are very different methods, but all are trendfollowing. If the sensitivity of all three systems is similar (as determined by the number of trades per year), the equity patterns will also be similar. For system diversification, it is best to select strategies with different functional attributes. For example, the following list gives systems that are likely to be less correlated and techniques within each method that tend to be different.

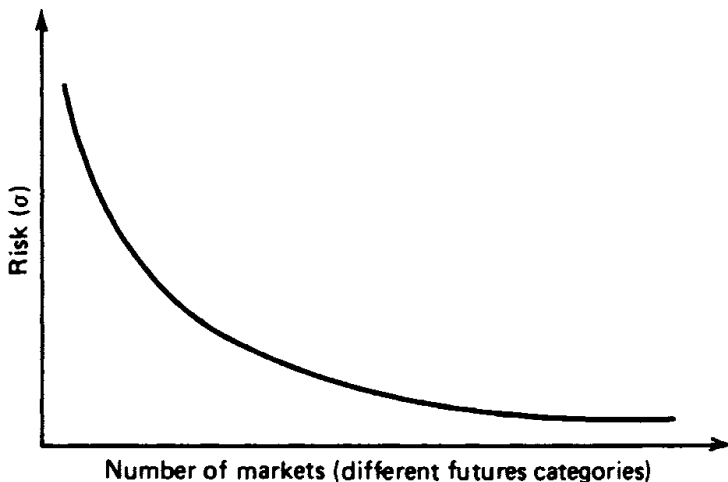
- a. Trendfollowing (moving averages or pointandfigure)
- b. Countertrend (stochastic or contrary opinion)
- c. Spreading (interdelivery, intercommodity, arbitrage, product)
- d. Fundamental

All four techniques are very different. Fundamentals may be trending in nature but should have a longer time perspective. The four types of spreads all offer excellent

diversification.

- 3. Balanced risk. Equalizing risk is necessary if the selection of different commodities and systems is to offer proper diversification. Traditionally, price volatility or market value is used to equate risk; however, this method tends to concentrate trading in those products that are least active and less likely to be profitable. For example, in early 1986, corn was trading at \$3 per bushel and the S&P 500 Index at 200, making their contract values \$15,000 and \$100,000, respectively. Equalizing contract

FIGURE 236 Effect of diversification on risk.



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values would mean trading seven corn to one S&P even though the likelihood of profiting in corn is far less than that of the S&P

Equalizing risk must account for the way the trading model performs in the selected markets; most systems do best in volatile periods. Because the most profitable strategies require some substantial price move, they concentrate on markets that have greater volatility. Therefore, it is both easier and better to diversify by distributing the investment among different systems and evaluating only the correlations in equity. A dynamic capital allocation will be necessary as one system becomes successful and its contribution to both profits and risk becomes disproportionately large. Withdrawing trading capital from the more successful systems at such times will maintain equal risk among systems and stabilize equity patterns.

These three justifications for diversification have their negative side as well. Diversification can mean lower profits. If there are equal returns from trading all markets and all systems, the diversified returns reduce risk and leave profits at the same high level. However, this never happens. It is not likely that silver and soybeans will be profitable at the same rate, nor is it to be expected that two systems will parallel themselves in performance using two distinctly different techniques.

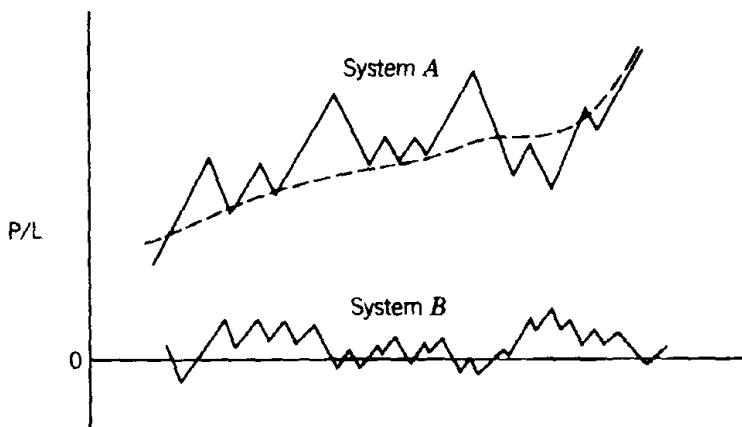
A classic example is the use of a system that actually loses money but has such a negatively correlated performance to one with a high return that the results of using them together are obviously better than either of them alone (Figure 237). Because system B returns only a small loss, it does little to affect the profitability of System A. It will, however, sharply reduce the equity drops by being profitable during periods when System A is losing.

Portfolio Calculations

Deciding which systems and markets should be traded at the same time, in an effort to reduce risk through diversification, is an entire field of

expertise called portfolio management. While markets have always changed, reflecting economic policy and the growth of participation, more recent years of globalization have made portfolio management much more difficult. As more institutions trade international markets as they do their own, they cause a higher correlation of price movements throughout the world. This increase in correlation between previously unrelated areas makes it more difficult to reduce risk through diversification, and makes previous asset allocations obsolete. One answer to this problem is simply to rebalance the portfolios more often, regrouping assets by their similar price movements.

FIGURE 237 Stabilizing equity using negatively correlated systems.



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Traditionally, the analyst builds up a portfolio from the expectations of the individual items to be traded. Even more sophisticated portfolios are constructed by selecting markets from groups that have been chosen, in advance, after performing a correlation analysis. Those that show different performance patterns qualify as potential assets in the portfolio. Once selected, the expected return of the portfolio is the weighted average of the expected returns on the individual components of the portfolio," assuming each component is invested with the same percentage of the total.

$$E(R) = w_1E(R_1) + w_2E(R_2) + \cdots w_nE(R_n)$$

$$= \sum_{i=1}^n w_iE(R_i)$$

The worth of a portfolio is not only its return, but its risk; therefore, the variance of the portfolio becomes an important criterion in deciding which combination of assets create the best results:

$$\sigma_R^2 = \sum_{i=1}^n w_i^2 \sigma_i^2 + \sum_{i=1}^n \sum_{j=1}^n w_i w_j C_{ij}$$

where σ_i^2 is the variance of the returns of market i and the returns of market j . The C_{ij} is the product of their standard deviations times the correlation coefficient between the same two markets:

$$C_{ij} = \text{corr}_{ij} \sigma_i \sigma_j$$

Given two portfolios with the same returns, the one with the smaller variance is more desirable; when the variances are the same, the portfolio with the highest return is best. For a portfolio of only two assets, the calculations needed for expected return and variance are:

$$E(R) = w_1 E(R_1) + w_2 E(R_2)$$

$$\sigma_R^2 = w_1^2 \sigma_1^2 + w_2^2 \sigma_2^2 + 2w_1 w_2 C_{12}$$

It is important to compare portfolios using this basic comparison of return and risk; however, it is not the entire picture. When evaluating the relationship between a large number of data points, there may be only one case in which an extreme price movement would have caused a fatal loss of equity. That one case can be lost in the statistics, because the large number of normal cases overwhelm one extreme. For safety, it is necessary to also look at the maximum portfolio loss. In addition, we must assume that the largest historic loss will be exceeded sometime in the future, if only by chance (consider the number of heads or tails in a row based only on the number of coin flips). Ideally, we should try to imagine the worstcase scenario, in which globalization increases the correlations, and the past events are not fully representative of future events.

Spreadsheet Approach

A practical way of evaluating a portfolio without requiring special mathematical knowledge or expensive software is to use a spreadsheet program. Using a classic stock and bond mix, Table 232 shows the monthly returns of the S&P 500 (S&P) and the Lehman Brothers Treasury Index (LBTI) combined into a portfolio of 60% stocks and 40% bonds. Columns B and C show the monthly percentage returns of these two inputs and columns E and F have the corresponding cumulative returns. At the bottom of columns B and C are some basic calculations that describe the performance. The S&P has an annualized return of 16.41% with a monthly standard deviation of 3.32%; bonds have a 7.65% return with a 2.61% standard deviation.

8 Peter L. Bernstein, *The Portable MBA in Investment* (John Wiley & Sons, 1995, p. 252)

TABLE 23-2 Portfolio Evaluation of Stocks and Bonds

Percentage Change

(A)	(B) S&P	(C) LBTI	(D) Stk + Bnd	(E) S&P
Jan 94	3.40	2.44	3.02	3.40
Feb 94	-2.71	-4.03	-3.24	0.69
Mar 94	-4.00	-4.22	-4.09	-3.31
Apr 94	1.28	-1.36	0.22	-2.03
May 94	1.64	-0.61	0.74	-0.39
Jun 94	-2.45	-0.09	-1.51	-2.84
Jul 94	3.60	3.03	3.37	0.76
Aug 94	4.10	-0.53	2.25	4.86
Sep 94	-2.45	-3.09	-2.71	2.41
Oct 94	2.25	-0.43	1.18	4.66
Nov 94	-3.64	0.48	-1.99	1.02
Dec 94	1.48	2.42	1.86	2.50
Jan 95	2.59	2.68	2.63	5.09
Feb 95	3.90	2.88	3.49	8.99
Mar 95	2.95	0.64	2.03	11.94
Apr 95	2.94	1.78	2.48	14.88
May 95	4.00	7.90	5.56	18.88
Jun 95	2.32	1.06	1.82	21.20
Jul 95	3.32	-1.64	1.34	24.52
Aug 95	0.25	2.13	1.00	24.77
Sep 95	4.22	1.73	3.22	28.99
Oct 95	-0.36	2.93	0.96	28.63
Nov 95	4.39	2.57	3.66	33.02
Dec 95	1.93	2.67	2.23	34.95
Jan 96	3.26	-0.02	1.95	38.21
Feb 96	0.69	-4.82	-1.51	38.90
Mar 96	0.79	-1.85	-0.27	39.69
Apr 96	1.34	-1.72	0.12	41.03
May 96	2.28	-0.04	1.35	43.32
Jun 96	0.22	2.10	0.97	43.54
Jul 96	-4.57	0.00	-2.74	38.97
Aug 96	2.11	-1.34	0.73	41.08
Sep 96	5.63	2.74	4.47	46.71
Oct 96	2.76	3.94	3.23	49.47
Nov 96	7.56	3.32	5.86	57.03
Dec 96	-1.98	-2.34	-2.12	55.05
Jan 97	6.25	-0.84	3.41	61.30
Feb 97	0.78	-0.01	0.46	62.08
Mar 97	-4.10	-2.44	-3.44	57.98
Apr 97	5.97	2.34	4.52	63.95
May 97	6.09	1.14	4.11	70.04
Jun 97	4.48	1.94	3.46	74.52
Jul 97	7.96	5.89	7.13	82.48
Aug 97	-5.60	-2.87	-4.51	76.88
Sep 97	5.48	2.84	4.42	82.36
Oct 97	-3.34	3.34	-0.67	79.02
Cum	79.02	32.64	60.47	
AROR	16.41	7.65	13.13	
StDev	3.32	2.61	2.71	
Ratio	4.94	2.93	4.84	

deviation. The ratio of AROR to standard deviation shows that the stock

market has been returning a much better reward to risk ratio during these 4 years.

Using the standard 60% stock and 40% bond portfolio, column D (row 5) becomes $+B5*.6 + C5*.4$ and column G becomes the cumulative value of that portfolio. When the same statistics are calculated for the mix, the AROR is 13.13% with a standard deviation of 2.71%. As expected, the return of 13.13% is about 60% of the difference between the bond and S&P returns; however, the standard deviation has increased only 14% (rather than 40%) of the difference between the two initial standard deviations. The ratio of 4.84 is very close to the S&P ratio, reflecting the sharp drop in risk due to combining these two assets. This easy method allows us to look for maximum drawdown, plot the original assets and final portfolio, and even apply a strategy to the new equity stream.

INDIVIDUAL TRADE RISK

The first line of Me in controlling risk is the individual trade, although sequences of trades are also an important consideration. Trades can be viewed as one continuous event for the purpose of assigning risk; alternately, a strategy may consider separating the trade into two or more parts, for example (1) from the time of entry until the trade becomes profitable, and (2) from the time it is profitable until the end of the trade.

Risk on Initial Positions

We associate the entry point of a trade with a period of greatest uncertainty. Depending on how quickly you anticipate the new trade, prices are either about to change direction or have just changed. Each type of trading method has its own intrinsic risk associated with initial entries. The trend philosophy will take small, frequent losses and reenter the trade as many times as necessary., the breakout technique will only limit losses by the size of the current trading range. It is not clear that the accumulated sequential losses of the trend method is less than a single loss in the breakout approach; and, in exchange for these two distinct approaches, the profit profile is also different.

Additional Risk Control

Most traders prefer specific risk controls added to the one that occurs naturally when the trading method reverses position. These are generally considered stops, because they are converted to price levels and subsequently into orders that win force the exit for a current position. Three of the more general approaches to determining the level of individual trade risk are:

1. An estimate based on initial margin, for example, 50010 to 70% of initial margin. This is loosely related to longterm volatility and lags considerably` An estimate of longterm volatility may be a more satisfactory alternative.
2. A percentage of the portfolio, for example, 1.0% to 2.5%. This concept of equalizing risk (and perhaps reward) across all markets is very popular; however, it is not sensitive to individual markets, and as with many stops, imposes artificial overrides. if the volatility becomes very high, as in the case of the S&P, then this risk level could be reached on every trade causing consistent losses. It is,

therefore, necessary to determine when a market with exceptional volatility should be removed from the portfolio.

3. The maximum adverse excursion determined by historic evaluation. " A stop is placed just beyond the maximum adverse excursion for each trade, or 2.5%, whichever is smaller.

Tushar Chande and Stanley Kroll, *The New Technical Trader* (John Wiley & Sons, 1994).
"John Sweeney, *Campaign Trading* (John Wiley & Sons, New York, 1997).

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Stops

Stop orders provide the ability to control risk most of the time. The reason it is not all the time is that exchange-traded markets can gap open, leaving your stop far behind. When stops are placed very close to the market, they are hit with a frequency resembling a random distribution; this is not particularly helpful to performance unless you only want to remain with a trade if it performs properly from the beginning. When stops are placed much farther from the current price levels, they can serve to protect you from extreme losses, but not always. When a price shock occurs, stops are often filled far from their intended level and can actually be filled at the worst point of the move. A system should not be profitable because of stops, but must work before stops are introduced.

If stops are to work, they must be based on values other than an arbitrary financial limit. Some worthwhile possibilities that change with the market are:"

1. Advance the stop by a percentage of price, as in Wilder's parabolic system.
2. Use a swing high or low point, based on a percentage minimum swing.
3. Use the highest high or lowest low of the recent n periods.
4. Apply a method such as Kaufman's Adaptive Moving Average (KAMA) as a stop.
5. Adjust the stop by the volatility, such as three times a 10-day average true range.

Standard Deviation Stop

As a sound statistical measurement of risk, the standard deviation can be used to determine stop-loss levels. In a method called the Devstop, Cynthia Kase uses the following steps to create stop-loss levels for both long and short positions:

1. Calculate the true range (TR) of the past 2 trading days using the highest high and lowest low of the 2-day period.
2. Calculate the moving average AIR of TR (in step 1), using 30 periods for intraday charts and 20 periods for daily charts.
3. Calculate the standard deviation of the true ranges in step 1 using the same period as in step 2.
4. The stop-loss values are $DDEV = ATR + (f \times SDEV)$, where $f = 1, 2.06$ to 2.25 , and 3.20 to 3.50 , and where the larger values of the pairs correct for skew and the larger numbers allow for larger risk.
5. The devstop for long positions is Trade high $DDEV$; the devstop for short positions is Trade low $+ DDEV$.

This method adjusts for volatility using standard statistical measurement and is applied to the extreme profit of a trade to prevent

unnecessary loss of equity.

Kaufman on Stops

As with many techniques, the use of stops has both good and bad features. The good aspects are summarized in the increased control of risk in particular, the unexpected, extremely large risk. It is an added assurance that volatility will not cause losses that are out of proportion to system performance and expected returns.

Ideally, a Stop order entered into the market is expected to automatically get you out of a position when prices move against you. It has the advantage of forcing the trader to decide, in advance, the size of the maximum loss, so that risk is under control. It avoids

Chande and Kroll (see footnote 9).

Cynthia Kase, "Redefining Volatility and Position Risk," *TecAmical Analysis of Stocks & Commodities* (October 1993).

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lastminute decisions and the temptation to hold a losing position with the hope that prices will recover.

Stops are normally resting orders; that is, they are held by the floor broker to be executed when the price is reached. For the purposes of discussion, a stop will be any form of an order that is intended to limit losses to a fixed amount, whether the order is placed in advance or monitored realtime.

Risk Protection or False Hope?

The use of stops, or the intent to limit losses to a predetermined, fixed amount may give a false sense of security. For example, a Stop order that is reached during an illiquid or quiet market will result in large slippage; during a fast market, or a price jump, it will often result in the worst fill. Large traders cannot enter stops because they will move the market and guarantee substantial slippage.

Market Noise and the Frequency of Stops

The use of small stops, or the trading practice of exiting a trade with a small loss, causes the total performance of a trend strategy to be worse. Small losses occur frequently due to market noise and are not an indication that the trading strategy, or the trend direction, is wrong.

Larger stoplosses offer some benefit for longerterm trading, when high volatility has caused the natural system stop to be very far away. Large stops may help reduce the risk of a price shock, but not always. Stops may reduce the performance volatility of a portfolio simply by causing more time out of the market.

Theoretically, the purpose of using a stoploss order is to limit each loss to a controlled amount, and generate a performance profile with a reasonable ratio of average profits to average losses (for example, 2 : 1). In addition, a trader would like to have at least onehalf of all trades profitable. Unfortunately, the market does not work this way. It is not possible to control both the reward/risk ratio and the percentage of profitable trades.

Noise is the term given to erratic and unpredictable price movements. It is most often associated with relatively small moves, but can actually be any size. Noise is caused by traders entering and exiting the market with different objectives and different time horizons. For example,

an institutional investor adds positions because of new funds from its clients; Russia sells gold to pay for a wheat purchase; or, an auto company liquidates part of its stock portfolio to cover foreign exchange losses. Because each event is unrelated to the other, and there are so many of them, the total picture of this noise creates a random distribution. This pattern has many of the properties of a random number distribution, in particular, erratic prices (noise) that are twice as large occur half as often.

Total Losses Are Constant

If noise is very similar to a random distribution, then the number of occurrences times the size of the move will be very close to a constant value. The following is a typical result of setting stops of different sizes:

In reality, this pattern may vary slightly from market to market; however, the cost of slippage will usually be large enough to cause the net losses to be similar. In addition, the

Size of Stop	No. of Occurrences	Size of Loss
5 pips	20	100 pips + slippage
10 pips	10	100 pips + slippage
20 pips	5	100 pips + slippage

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more frequent trades must also have additional transaction costs, with a chance of larger slippage from time to time; therefore, the strategy that uses smaller stoplosses should perform worse than the strategy with larger stops. A StopLoss Can Conflict with the Trading Strategy

Combining a small stoploss with a trendfollowing system is very likely to conflict in purpose. If a trending system gives one new trend signal each month, but the stoploss is so small that it would be reached once each week, it would be very difficult to stay with a system position. Once stopped out, if the market turns and moves in the direction of the trend, the system is proved right but you have no position. It is necessary to create a reentry strategy that can be unnecessarily complex.

If every time you are stopped out of a trade, the price continues in the same direction until a reverse position is signaled, then it follows that the selection of the trend period is too slow. Rather than exit the trade when the stop is reached, the system should be reversing its position. By shortening the trend calculation period, the need for a stop is eliminated.

Testing Stops over Ten Years

Table 233 gives the pattern of performance for a simple moving average trading system with calculation periods from 5 to 300 days and stops from .02% to 10%. Four major markets were selected, two stocks and two futures markets. The smallest stoploss of 2% appears on the left, and the largest of 10% and no stop NONE appear on the far right. Overall, the performance of the trend program without a stop is most consistent for the range of trend periods, although specific stops can be better for some intervals. It may be noted that there is a pattern in Siemens, in which the

best performance runs diagonally from the upper left toward the bottom right, indicating that the size of the optimum stoploss may be related to the speed of the trend, but this pattern is not the same for the other markets tested and, therefore, it may be the result of a single trade, such as the crash of 1987, and not a robust relationship. Table 234 shows the same results for the Deutschmark and Eurodollars in terms of riskadjusted returns, in which the returns are divided by one standard deviation of the equity changes. In general, these results were the same as the unadjusted ones in Table 233.

Managing Risk with and without Stops

Despite the conclusion that the placement of fixedlevel stops causes a trade to be stopped out arbitrarily, it is difficult to trade without a clear idea of risk. For longerterm positions, a fixed stoploss may help in the case of catastrophic risk. Before a stoploss is used, it should be tested and compared with system performance that does not use a stop. Careful selection of the trading strategy may provide adequate risk control with a separate stoploss.

While fixed stops do not seem to enhance a trading program, a stop based on support and resistance levels may be quite different. it is already known that a breakout system, which enters on a new high and reverses on a new low, assumes the risk of the range defined by the difference between the high and low. This is analogous to the size of a supportresistance range. Because this range varies with market volatility and offers a view of risk that contrasts with a trend system, the combination of the two may improve net performance.

The safest way to reduce risk is simply by reducing the size of your positions. Trading a smaller portfolio, a lower margin to equity ratio, is the simplest approach to risk reduction and does not conflict with the underlying trading strategy. in the final analysis, the one who can profit by trading the smallest amount will be hurt the least when a price shock hits the market.

TABLE233 Results of Tests Comparing Trend Period and Size of Fixed Stops* Annualized Rate of Return (Adjusted for 25% Drawdown)

Stop-Loss in Whole Percent											
	.02	.05	.10	.15	.25	.50	1.00	2.00	4.00	7.00	10.00
<i>a. Chrysler Motors: 2,329 Days (1/05/84 to 3/18/93)</i>											
5	-2.8	-2.8	-2.7	-2.7	-2.7	-2.8	-2.8	-2.7	-2.8	-2.8	-2.8
10	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8
25	-2.8	-2.8	-2.8	-2.7	-2.8	-2.8	-2.6	-2.6	-2.6	-2.6	-2.6
50	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.2	-2.3	-2.2	-2.2	-2.2
75	-1.2	-1.2	-1.2	-1.4	-1.4	-1.5	-1.5	-1.6	-1.4	-1.5	-1.5
100	-1.5	-1.5	-1.5	-1.6	-1.7	-1.9	-6	-7	-5	-6	-6
150	5.8	5.7	5.7	5.3	5.4	4.9	4.5	4.0	3.6	3.5	3.5
200	2.2	2.2	2.2	1.9	1.7	1.6	1.4	2.8	2.7	2.7	2.7
250	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-4	-1	2.0	2.0
300	3.6	3.6	3.4	3.4	3.2	3.1	3.0	2.5	2.4	2.4	2.4
<i>b. Siemens: 1,452 Days (2/3/87 to 11/23/92)</i>											
5	1.5	1.5	2.1	1.6	.9	1.4	1.9	1.5	1.2	1.2	1.2
10	11.8	11.7	12.0	11.4	10.6	8.5	8.2	7.5	6.7	6.0	6.0
25	10.1	10.1	9.4	8.8	7.4	6.8	5.0	3.7	3.5	3.0	3.0
50	6.3	6.3	6.1	5.6	8.9	6.7	6.7	8.4	8.8	7.7	7.7
75	9.8	9.4	11.4	11.6	12.1	11.1	8.3	10.0	9.7	8.7	8.7
100	5.2	5.2	4.8	4.9	4.1	3.1	4.8	5.9	5.9	5.3	5.3
150	5.0	4.9	4.9	5.0	5.0	4.2	3.0	4.7	7.8	7.7	7.0
200	3.6	3.6	3.6	3.2	2.9	2.2	2.9	1.8	2.9	2.8	2.8
250	4.5	4.4	4.4	4.3	3.9	3.3	4.4	5.2	4.9	4.9	4.9
300	4.4	4.4	4.4	4.2	5.4	4.9	4.1	2.7	2.4	2.4	2.4
<i>c. Deutschemark: 2,570 Days (11/24/82 to 11/23/92)</i>											
5	-1.9	-1.9	-1.9	-1.9	-1.9	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8
10	-1.4	-1.1	-1.0	-1.0	-1.1	-7	-6	-6	-6	-6	-6
25	1.7	2.6	3.6	2.9	3.8	3.8	5.5	5.7	5.3	5.2	4.9
50	5.2	6.9	6.8	6.4	3.7	12.8	11.0	11.5	10.8	10.8	10.8
75	3.4	4.8	6.1	5.6	8.5	13.4	10.0	8.7	7.8	7.6	7.6
100	5.3	7.2	8.5	8.3	4.5	10.8	11.5	7.4	9.1	7.5	7.5
150	.5	.3	.0	-.4	1.6	8.1	6.8	7.7	5.3	3.6	3.6
200	.7	2.0	1.7	1.1	10.1	11.7	7.7	9.6	6.9	7.6	7.0
250	8.0	9.1	8.1	8.1	6.5	5.5	7.2	8.8	5.4	11.0	9.1
300	.7	.4	.2	-.1	.5	5.1	5.1	5.6	4.3	12.3	10.7
<i>d. Eurodollars: 2,556 Days (1/03/83 to 12/14/92)</i>											
5	1.2	1.3	1.4	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1
10	1.8	2.1	3.1	2.7	2.7	2.6	2.7	2.7	2.7	2.7	2.7
25	3.8	3.0	6.7	6.1	8.2	7.4	7.4	7.4	7.4	7.4	7.4
50	4.0	8.5	10.5	7.7	8.1	7.8	7.7	7.7	7.7	7.7	7.7
75	6.5	10.2	8.1	9.2	10.8	10.0	9.9	9.9	9.9	9.9	9.9
100	7.1	4.8	8.9	6.3	6.4	7.2	7.8	7.8	7.8	7.8	7.8
150	4.1	1.8	2.9	2.6	6.4	5.0	7.6	7.6	7.6	7.6	7.6
200	7.3	5.4	.8	.4	2.9	5.9	6.5	6.5	6.5	6.5	6.5
250	1.1	-.8	-.8	.1	4.1	3.8	6.9	5.6	5.6	5.6	5.6
300	.2	-.1	-.6	-.8	.3	6.7	5.6	5.4	5.4	5.4	5.4

* Exponential smoothing was used to create a trend with buy and sell signals given when the trendline turned up or down, respectively. apply to absolute losses, all orders were executed at the close of the day, and there were no commissions or slippage charged. Although improve performance in specific cases, there does not seem to be a consistent pattern. Smaller stops are especially erratic, as the trend increase in length, often showing alternating better and worse performance.

Comparison of Cash Return versus RiskAdjusted Return

	Stop-Loss in Whole Percent										
	.02	.05	.10	.15	.25	.50	1.00	2.00	4.00	7.00	10.00
Deutschemark: 1,030 Days (11/22/88 to 11/23/92)											
Annualized Rate of Return (on Cash, in Percent)											
5	-7.5	-7.1	-7.3	-8.3	-9.9	-8.5	-7.1	-7.1	-7.1	-7.1	-7.1
10	-6.8	-5.0	-5.3	-6.2	-7.6	-7.0	-4.4	-4.3	-4.3	-4.3	-4.3
25	2.8	5.5	5.4	5.4	5.4	4.2	6.5	7.4	7.4	7.4	7.4
50	5.6	10.2	9.9	10.1	9.6	8.3	8.3	8.7	8.0	8.0	8.0
75	2.8	2.2	1.6	1.6	5.0	7.0	5.1	5.0	3.6	3.4	3.4
100	1.3	4.2	3.6	3.5	7.4	5.4	8.7	8.6	9.3	9.1	9.1
150	1.2	.9	.7	.7	-1.1	7.6	9.3	11.2	8.8	7.5	7.5
200	5.3	9.1	8.9	8.7	8.2	6.4	7.9	9.7	7.0	5.2	4.4
250	5.9	8.3	8.1	8.0	7.7	6.7	6.1	7.9	5.2	5.6	4.4
300	2.0	1.8	1.5	1.2	.9	4.5	6.4	8.1	5.4	6.6	5.4
Annualized ROR (Adjusted for 25% Drawdown)											
5	-3.7	-3.6	-3.6	-3.8	-4.2	-4.0	-3.6	-3.6	-3.6	-3.6	-3.6
10	-3.9	-2.8	-2.9	-3.2	-3.6	-3.5	-2.5	-2.4	-2.4	-2.4	-2.4
25	2.7	4.8	4.6	4.6	4.6	3.3	7.1	10.9	10.9	10.9	10.9
50	12.7	23.3	22.5	25.2	21.7	17.3	16.0	16.8	15.5	15.5	15.5
75	4.4	3.6	2.2	2.2	7.8	14.5	7.5	6.6	4.4	4.2	4.2
100	2.8	8.7	7.0	6.8	18.1	9.5	18.1	11.3	19.1	18.6	18.6
150	3.7	2.4	1.7	1.7	-1.7	12.1	12.0	14.6	10.8	8.3	8.3
200	14.0	22.0	19.3	19.2	17.1	13.4	13.2	15.1	9.1	5.9	5.9
250	14.7	18.8	17.6	16.7	16.0	12.8	9.9	12.9	7.4	8.2	7.4
300	5.7	4.5	3.4	2.8	1.9	8.3	9.8	12.8	7.0	10.3	9.8
Eurodollars: 1,042 Days (11/22/88 to 12/14/92)											
Annualized Rate of Return (on Cash, in Percent)											
5	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3
10	.9	.9	1.0	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
25	.3	.4	.9	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3
50	.3	.5	1.0	1.3	1.6	1.6	1.6	1.6	1.6	1.6	1.6
75	.7	.8	1.1	1.1	1.3	1.3	1.3	1.3	1.3	1.3	1.3
100	.9	.8	1.0	1.0	1.1	1.0	1.0	1.0	1.0	1.0	1.0
150	.0	.1	-.1	-.1	.6	.9	.9	.9	.9	.9	.9
200	.1	.1	.1	.1	.7	1.1	1.1	1.1	1.1	1.1	1.1
250	.2	.2	.2	.2	.9	1.2	1.2	1.2	1.2	1.2	1.2
300	.2	.3	.2	-.3	.4	.6	.6	.6	.6	.6	.6
Annualized ROR (Adjusted for 25% Drawdown)											
5	2.9	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
10	21.9	22.4	25.7	19.5	25.9	25.9	25.9	25.9	25.9	25.9	25.9
25	2.9	4.6	11.3	28.6	32.9	32.9	32.9	32.9	32.9	32.9	32.9
50	7.6	12.6	23.8	33.0	38.8	38.8	38.8	38.8	38.8	38.8	38.8
75	18.5	20.7	27.4	27.1	32.6	32.0	32.0	32.0	32.0	32.0	32.0
100	22.1	18.3	25.9	25.6	28.5	25.6	25.6	25.6	25.6	25.6	25.6
150	.7	1.4	-1.3	-1.3	7.3	11.4	10.9	10.9	10.9	10.9	10.9
200	3.5	1.7	1.2	1.0	9.1	13.8	14.1	14.1	14.1	14.1	14.1
250	4.4	5.9	4.9	4.4	16.8	14.8	15.1	15.1	15.1	15.1	15.1
300	4.3	6.5	5.6	-3.4	4.1	5.2	5.4	5.4	5.4	5.4	5.4

* The pattern in the "NONE" column (no stops) shows that the risk-adjusted results, in general, are more consistent than unadjusted results.

RANKING OF MARKETS FOR SELECTION

Choosing the right market to trade at the right time would be a difficult task. To accomplish this, there are a number of ways to measure market strength, from standard statistical techniques to more complex rule-based systems. To ensure some special characteristic of price movement. To trade using a system that targets this type of price movement, a correlation coefficient, r^2 , to rank the trend over 20 days. Probably the best choice of a trend-following system, using a

It may be interesting to list a number of trend-ranking systems and their values in a table over various time periods.¹³ For each system, the value below can be calculated for periods of 5, 10, 20, and 40 days.

1. Correlation coefficient, but no less than .25
2. Sum of the net \$ movement over n , $2 \times n$, and $4 \times n$
3. Slope of an n -day regression converted to 1-day \$
4. Wilder's ADX, but no less than .20
5. Average absolute value of price changes

Each measurement will need to have threshold values that determine when they represent significant trends. For the correlation coefficient, anything below .25 is most likely to be a sideways market; similarly, Wilder's ADX would need to be above .20 to indicate a trend. If the results are erratic, it may be necessary to smooth the last 3 days of each value. In the case of item 5, higher volatility is often associated with greater profits and greater risk for a trendfollowing system; therefore, a careful look at how ranking affects performance is warranted.

Commodity Selection Index (CSI)

Among Wilder's trading tools is the Commodity Selection Index (CSI), a calculation for determining which products are most likely to make the greatest move for each dollar invested. In this case, the movement measured is directional and, therefore, may apply more to trending models. The CSI combines directional movement, volatility, margin requirements, and commission costs into an index that allows for comparison and selection.

Directional Movement

The trending quality of the market, as defined by Wilder, begins with directional movement, the greater of either:

1. Plus DM (+DM), today's high minus yesterday's high, or

2. Minus DM (DM), today's low minus yesterday's low

The directional movement is either up or down, whichever is larger. It is the largest part of today's range which is outside yesterday's range. When an inside day occurs, the directional movement is zero (Figure 238).

DM is expressed relative to the daily range (high minus low), defined as today's true range (TR1), the larger of the following:

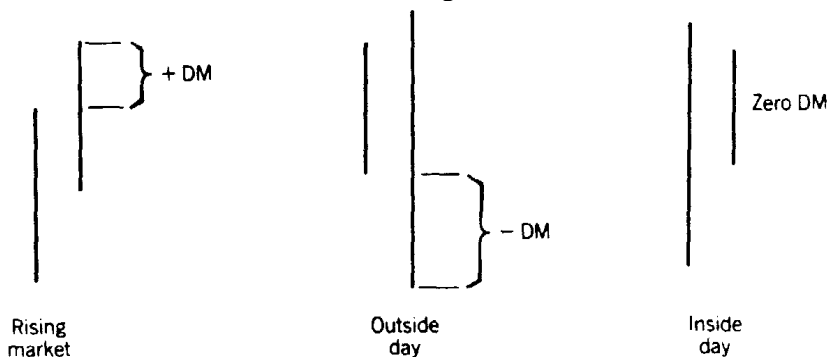
1. Today's high minus today's low
2. Today's high minus yesterday's close
3. Yesterday's close minus today's low

Based on an idea suggested in Chande and Kroll, *The New TecAmical Trader* (John Wiley & Sons, 1994).

"J. Welles Wilder, Selection and Direction" in *TecAmical Analysis in Commodities*, Perry J. Kauffman (ed.) (John Wiley & Sons, New York, 1980).

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FIGURE 238 Defining the DM.



The true range is always positive.

The relationship of the directional movement to the true range is called the Directional Indicator. Today's directional indicator is calculated using either the plus DM or the minus DM, whichever is greater.

$$+DM14 = + \frac{DM14}{TR14} \quad \text{or} \quad -DM14 = - \frac{DM14}{TR14}$$

Once the first DM 14 is calculated, an average off technique is used to find each successive DM14 as follows:

$$\text{Today's } +DM14 = \text{prior } +DM14 - \frac{\text{prior } +DM14}{14} + \text{today's } +DM14$$

The same procedure is followed for the true range:

$$\text{Today's } TR14 = \text{prior } TR14 - \frac{\text{prior } TR14}{14} + \text{today's } TR14$$

These results can also be produced using a smoothing constant of .93 as

follows:

Today's +DM14 = 93 X (prior +DM14) + today's +DM 1

Today's DNI 14 = .93 X (prior DNI 14) + today's DNI 1

Today's TRI.4 = .93 x (prior TR14) + today's TRI

At this point, the Directional Indicator can be used as a trading indicator. and is the subject of the next section; however, Wilder's interest was to use this in a more complete concept. Once the +DM14, DM14, and the TR14 are calculated, +DI1* and DI 14 follow. and the true directional movement is the difference between +DI 1 1 and DI 1 1. 'When an upward trend is sustained, the +DI14 becomes larger, the DI 14 becomes smaller, and the true directional movement becomes greater. This is then normalized to allow it to be expressed as a value between 0 and 100.

$$DX = \frac{+DI14 \text{ minus } -DI14}{+DI14 \text{ plus } -DI14} \times 100 = \frac{DI \text{ difference}}{DI \text{ sum}} \times 100$$

where multiplying by 100 converts the percentage to a whole number smoothed out using a 14-day average (or 0.07 smoothing constant). a *age Directional Movement Index* (ADX).

$$ADX(\text{today}) = ADX(\text{prior}) + .07 \times [DX(\text{today}) - ADX(\text{prior})]$$

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One last adjustment is made to the extreme variance of the ADX by taking the 14day difference of ADXs. This final rating is called the Average Directional Movement Index Rating (ADXR),

$$ADXR = \frac{ADX(\text{today}) + ADX(14 \text{ days ago})}{2}$$

The ADX and ADXR are shown plotted together in Figure 239 The ADX is seen to oscillate about the ADXR. Measuring the amplitude of the ADX from the zero line. a higher amplitude means higher directional movement and a stronger trend, whether up or down. The peaks are always the extremes in the same direction as the trend. If the major trend was down, the peaks would be extremely low points and the valleys would be relatively high points. The greater the distance between the peaks and valleys, the greater are the reactions to the trend.

All this leads to the Commodity Selection Index (CSI), which is calculated as:

$$CSI = ADXR \times ATR14 \times \left[\frac{V}{M} \times \frac{1}{150 + C} \right] \times 1$$

where ADXR = average directional movement index rating

ATR14 = 14day average true range

V = conversion factor; value of a 1c move (in dollars)

M = margin (in dollars)

C = commissions (in dollars)

Note that for a particular commodity, the values in brackets do not change. By calculating them once and calling that value K, the CSI can be expressed as:

$$\text{CSI} = \text{ADX} \times \text{ATR}_{14} \times K$$

A portfolio allocation can be chosen by calculating the CSI daily (or weekly) for each commodity. Simply select those products to trade that have the highest CSI or allocate multiple contracts in proportion to their CSI value.

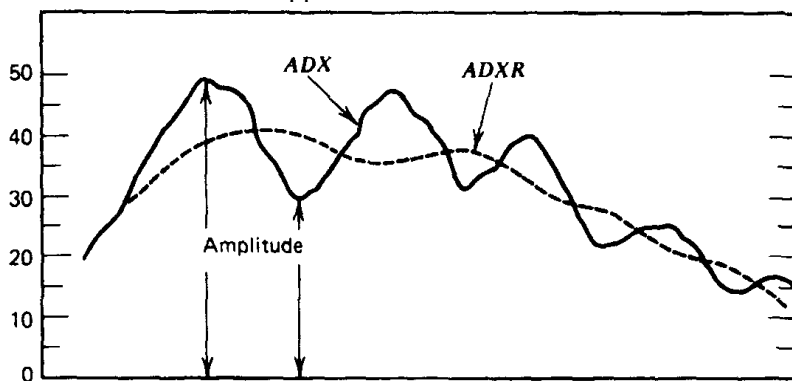
Optimizing Directional Movement

The +DI14 and DI14 are indicators that can be used in a simple trading strategy. Hochheimer, known for other studies of moving averages, crossovers, and channels, has defined the rules of a Directional Movement System in two ways. The first set of rules are:

For a general discussion of this topic, see Chapter 21.

Frank L. Hochheimer and Richard J. Vaughn, *Computerized Trading Techniques* 1982 (Merrill Lynch Commodities, New York, 1982).

FIGURE 239 Appearance of the ADX and ADXR.



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1. a. if the +DI crosses above the DI, enter a buy stop on the next day using today's high price. This order remains as long as it is not executed and +DI remains higher than DI.

If the DI crosses below the +DI, enter a sell stop on the next day using today's low price. Maintain this order until it is executed and while DI remains below +DI.

Hochheimer calls the first case "directional movement with delay." The second case is an immediate market entry following the crossing of the directional indicators:

2. a. If the +DI crosses above the DI, buy on the open of the next day.

- b. If the DI crosses below the +DI, sell on the open of the next day.

In both cases the system is always in the market.

Before seeing the actual results, it is possible to generalize the expected performance.

1. Case 2 must have more trades than case 1 as a result of always taking a position when a crossing occurs.
2. Because there is no commitment to the trade (i.e., no channel), there could be frequent whipsaws in case 2.
3. Because case 1 uses the high and low of the prior day, its entry prices will always be equal to or worse than case 2.
4. If the Directional Indicator gives a highly reliable signal, it would be better to enter immediately, as in case 2.

Parameters Defined

The purpose of the optimization was to see if changes in the time intervals caused improvements in results. Hochheimer chose the following parameters to test:

1. The +DM was calculated from 7 to 20 days.
2. The DM varied from 5 above to 5 below the +DM value.
3. Two true ranges (TR) were calculated, the first using the weight of the +DM, the other using the weight of the DM.

The test data covered all information available from 1970 to 1981.

Results

Selected results are shown in Table 235. The patterns of the two cases are as expected. Case 2 has more trades, with a higher percentage of losses and higher risk. The profit/loss shown in case 1 is generally higher than case 2, indicating that, even under ideal conditions, the RSI generates many false signals using these rules.

It can also be seen that those markets with a small amount of available data, Tbills, Tbonds, currencies, and gold, had the shorter intervals selected for calculation. By observing the tendency for the products with more data to use longer intervals, a standard set of days should have been chosen rather than allowing an apparent overfitting of the data.

The philosophy of these tests, however, should be questioned. Although the independent varying of the number of days in the +DM, DM, and TR accounts for all combinations, it seems illogical. The Directional Movement Indicator is intended to be a measurement of relative strength over a fixed time period; it produces a percentage from 0 to 100. In this study, the TR (the denominator) may have a time interval smaller than one of the +DM or DM, generating a value greater than 100.

The independent varying of the up and down segments of the indicator also allowed a longterm directional bias to appear. This can be seen in the optimum selection of those commodities with the shortest amount of data: the financials markets and the currencies. In case 2, almost all of the products with 11 years of data produced interval selections that were nearly identical, in the area of either 14 or 20 days.

Case I						
	Days	P/L	Equity Drop	No. of Trades	Days	P/L
Cocoa	22 17	\$43,083	\$-13,019	723	23 18	\$-4,117
Corn	21 20	26,456	-7,072	613	21 20	26,456
Cotton	18 21	37,495	-21,740	1256	24 19	29,765
Copper	18 20	219,639	-10,230	633	12 14	88,561
Deutschemark	8 13	140,538	-6,335	277	14 14	101,476
Gold	15 10	827,980	-10,740	504	16 12	664,390
Cattle	22 19	-7,850	-11,710	474	20 20	-14,860
Soybeans	16 20	254,495	-39,639	895	19 20	177,584
Silver	16 11	1,034,825	-82,870	788	22 17	351,360
T-Bills	3 7	37,840	-12,005	286	11 8	5,235
T-Bonds	8 7	185,371	-11,326	436	9 8	118,256

Kaufman's System Selection Indicator

A market's personality is in its price patterns. Some markets, such as the stock index, are very volatile with gradual sustained upward moves and fast, sharp drops. In contrast, Eurodollars are very steady, often trading high volume at the same price. Qualifying markets by noise allows you to decide which trading strategy is most likely to be successful. Lower noise favors trending systems and high noise makes countertrend techniques more appropriate.

The concept of noise has been discussed in numerous sections throughout this book, and it is again of great value when choosing which system to apply to a market, and identifying when a market is best treated as trending. In essence, noise is market movement that has no direction or one in which the amount of direction is overwhelmed by volatile erratic up and down movement. It is an undercurrent of unpredictable movement caused by a broad range of participants acting for their own individual objectives.

The calculation for noise can be found with examples in Chapter 17 ('Adaptive Techniques'). As a simple reminder, it is defined as the efficiency ratio, ER:

$$ER = \frac{\text{Net price change}}{\text{Sum of price changes as positive values}}$$

Time Frame

There always appears to be more noise over short time periods. That is because noise remains at about the same level, but price trends are not clear until they have persevered for at least a few days, and often for weeks. For a trend comparison we should avoid very shortterm trends; therefore, a 16day exponential smoothing will be used in the following comparison. To be certain that the efficiency ratio is stable, it will be calculated over a 65day period.

Results of Efficiency Ratio Selection

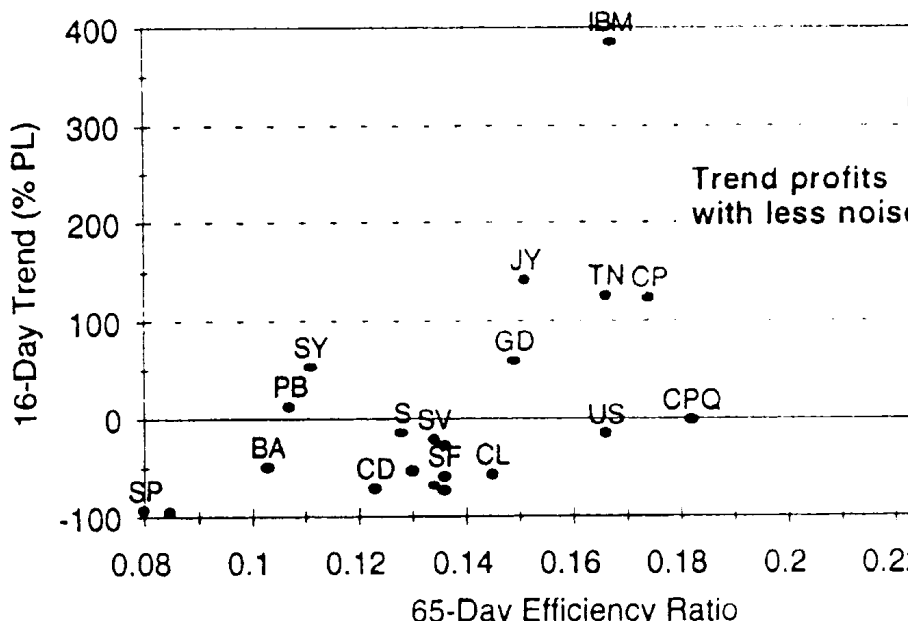
Figure 2310 shows that, when returns are compared using the

efficiency ratio, profits are clearly greater when the ER is high; losses are larger when the ER is low. Based on a broad sampling of markets, this is a very useful pattern for classifying markets. The greatest profits are in the upper right part of the diagram where there is less noise; the greatest losses are in the lower left corner where there is the most noise. We can conclude that

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FIGURE2310 Efficiency ratio and trend performance. A clear pattern can be seen when a longterm efficiency ratio (market noise) is plotted against the trend performance of a broad sampling of markets using a 16day exponential smoothing.

(65-Day Eff Ratio and 16-Day Trend)



When the efficiency ratio is high, then a trend system is a better strategy.
When the efficiency ratio is low, then a countertrend system is best.

in the second case, a countertrend approach does not mean that you must set a short position when the market is moving up. It can also mean taking profits on a long position when there is a countertrend sell signal, or building a long position when a countertrend buy signal occurs on a price drop. While the efficiency ratio is not specifically a directional indicator, it does seem to classify markets as trending or nontrending.

PROBABILITY OF SUCCESS AND RUIN

The relative size of trading profits and losses, the frequency of the losses, and the sequence in which they occur comprise the equity profile of traders and systems. This profile can be used to determine the capitalization necessary to maintain trading during the losing periods and allow the

system to return to its full potential. In investment terminology and probability theory, the level at which you no longer have enough money to continue trading is called the point of ruin, and the chance of getting there is the risk of ruin. The probability of the risk of ruin is normally expressed as

$$R = \left[\frac{1 - A}{1 + A} \right]^c$$

where $0 \leq R \leq 1$, 0 indicates no risk, and 1 certain ruin

$A = P - (1 - P)$, P is the proportion of winning trades, also
advantage

c = the beginning units of trading capital

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A system of trading that has 60% profitable trades and trading capital in \$ 10, 000 units will have a risk of ruin calculated as follows:

$$A = 0.60 - (1 - .060) = 0.20$$

$$R = \left(\frac{1 - 0.20}{1 + 0.20} \right)^c = \left(\frac{0.80}{1.20} \right)^c = \left(\frac{1}{3} \right)^c$$

When $c = 1$ (\$10,000), $R = 0.33$, and when $c = 2$ (\$20,000), $R = 0.11$. Therefore, the greater the trader's advantage or the greater the capital, the smaller the risk of ruin (Figure 2311).

When using profit goals, the chance of ruin should decrease as the goal becomes smaller. The relationship can be expressed as:

$$R = \frac{[1 + A]/(1 - A)]^G - 1}{[(1 + A)/(1 - A)]^{c+G} - 1}, \quad 0 \leq R \leq 1$$

where all terms are the same as above, and G is the goal in units of trading capital.

Wins Not Equal to Losses

The basic equations just presented are generally applied to gambling situations, where the size of profits and losses are the same. This requires that the percentage of winning events exceed the losing events to avoid ruin. Futures trading, however, often results in more losing trades than profitable ones and must, therefore, return much larger profits than losses. Such a structure is common to all conservation of capital, or trendfollowing, systems. This situation can be applied to the more complex form where

C_T = the total capital available for trading (in units)

C_R = the cutoff point, where level of ruin is reached ($C_R < C_T$)

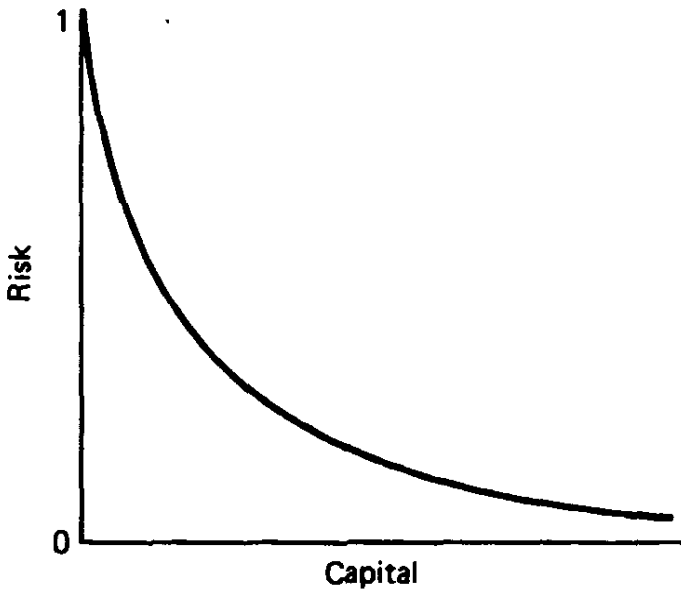
$C_A = C_T - C_R$, capital available to be risked

E = the expected mean return per trade, the probability-weighted average of the possible outcomes of the trade might take

$$E = \sum_{i=1}^N (PL_i p_i)$$

¹⁷ Fred Gehm, *Quantitative Trading & Money Management* (Revised Edition)

FIGURE 23.11 Risk of ruin based on capital.



where PL_i is the possible profit or loss value, and p_i is the probability ($0 < p_i < 1$).

E_2 is the expected squared mean return per trade, the probability of the squared values of a trade,

$$E_2 = \sum_{i=1}^N (PL_i^2 p_i)$$

where PL_i and p_i are defined above.

$$D = C_A / \sqrt{E_2}$$

$$P = 0.5 + E / (2\sqrt{E_2})$$

and the risk of ruin is

$$R = \left(\frac{1 - P}{P} \right)^D$$

Introducing an objective and a desired level of capital L , the risk of

$$R = 1 - \frac{[(1 - P)/P]^D - 1}{[(1 - P)/P]^G - 1}$$

where

$$G = 1/\sqrt{E_2}$$

As in the first situation, using equal profits and losses, the risk increases as the objective L increases. Ralph Vince, in *Portfolio Management Formulas* (Wiley, New York, 1990) derived similar results from P. Griffin's work, *The Theory of Blackjack* (Gamblers Press, Las Vegas, 1981), which claims to provide a "fair approximation" of risk. Vince's approach has been modified for convenience and given in a way that allows spreadsheet formulas:

Risk of Ruin = $((1 - P)/P)^A (\text{MaxRisk}/A)$

where the following terms are defined in the order needed for calculation:

AvgWin is the average winning trade (e.g., \$400)

AvgLoss is the average losing trade (e.g., \$200)

Investment is the amount invested (e.g., \$10,000)

ProbWin is the probability (percentage) of a winning trade (e.g., .40)

ProbLoss is the probability (percentage) of a losing trade (e.g., .60)

MaxRisk is the maximum part of the investment that can be lost, in percent (e.g., .25)

AvgWin% is @ABS(AvgWin/investment)

AvgLoss% is @ABS(AvgLoss/investment)

Z is the sum of possible events, ProbWin*AvgWin% ProbLoss*AvgLoss %

A is the square root of the sum of the squares of possible events,

$(\text{ProbWinAvgWin}\%^2$

$+ \text{ProbLoss.AvgLoss}\%^2)^{1/2}$

P is $.5*(1 + (Z/A))$

This can be written as the following spreadsheet example:

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Row		Col A	Description
1	AvgWin	400.00	Enter average win
2	AvgLoss	200.00	Enter average losi
3	Investment	10000.00	Enter initial capital
4	ProbWin	.40	Enter probability o
5	ProbLoss	.60	(1 – A4)
6	MaxRisk	.25	Enter maximum pa
7	AvgWin%	.040	@abs(A1/A3)
8	AvgLoss%	.020	@abs(A2/A3)
9	Z	.0040	A4*A7 + A5*A8
10	A	.0297	$(A4*A7^2 + A5*A8$
11	P	.5674	0.9444
12	Risk of Ruin	.1016	$((1 - A11)/A11)^(A$

in the above example, the risk of ruin is slightly greater than 10% based on historic data. The change in risk can be seen by varying the investment amount. Note that in row 11, when P = 1, the risk of ruin is 100%; therefore, P cannot be greater than 1.

COMPOUNDING A POSITION

At some point, all speculators find themselves adding to, or compounding, their position. Many traders view this as a means of concentrating on those commodities that have more potential. There are two lines of thinking among these traders. When a trade becomes more profitable, it is confirming its move and is thought to deserve more of a commitment than a trade that has not become profitable. On the other hand, by adding positions to a trade at preset intervals, the effect of a single poor entry point is reduced and a better average entry price is created. This latter technique is called scaledown buying in the securities industry.

The following sections will assume that positions are added based on profitability as a means of increasing leverage. There are a number of techniques used by experienced traders, but the time to add must be carefully selected. The situation chosen must have potential for a long

move with limited risk; the sustained consolidation period of a market that is priced near its historic lows would be a candidate. No matter how well chosen, each method will result in the largest holdings at the highest (or lowest) price; when the market reverses, losses occur on a larger base and profits will disappear quickly. Compounding a position is very fragile, hard work and must be watched cautiously for a changing market; there are enough stories of speculators who leveraged small capital into a large fortune in less than a year's time and then lost it all in a week. As in all investments, the risk balances the opportunities.

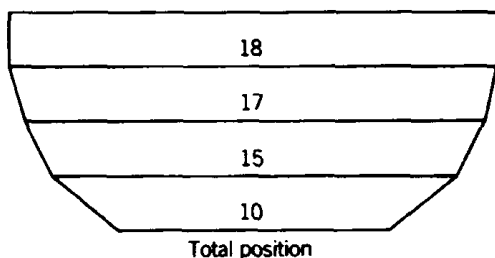
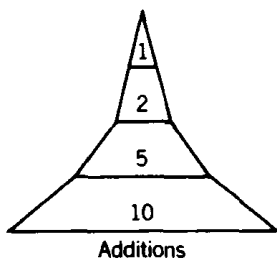
The ScaledDown Pyramid

The patterns used to compound positions can be represented geometrically as pyramids. The standard pyramid, or upright pyramid, has a larger base than its top. The largest portion of profits are developed early and an adverse price move is not as likely to be disastrous. The profitcompounding effect of this technique is comparably reduced. A favorite scaling method of this type adds onehalf of the prior position at each opportunity (Figure 2312a). The maximum number of contracts to be held must be planned in advance. The total position, if followed to completion, will be about twice the number of contracts that were initially entered; starting with 20 lots, 10, 5, 2, and 1 would be added, respectively.

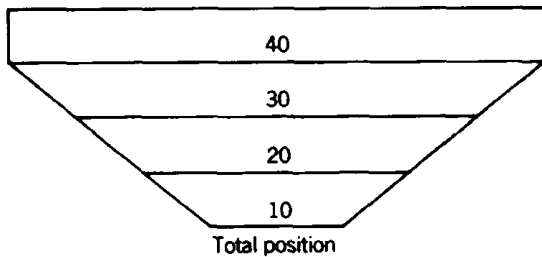
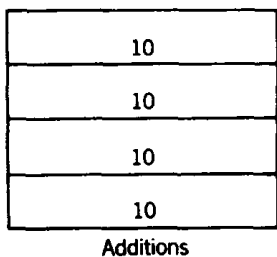
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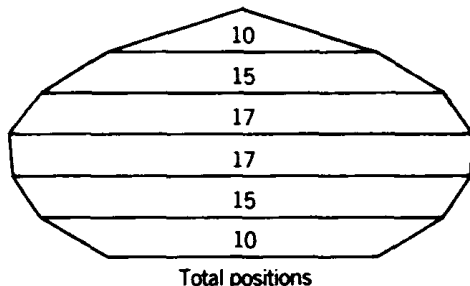
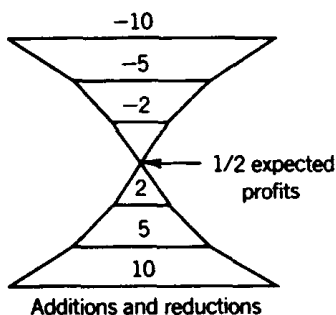
FIGURE 2312 Pyramid structure. (a) Scaleddown (upright) pyramid offers a small amount of compounding. (b) Adding equal amounts (inverted pyramid) gives maximum leverage. (c) Reflecting pyramid combines leverage and profit taking.



(a)



(b)



(c)

advantage of this or any other pyramiding method is that an initial loss will be based on a smaller number of contracts than the final commitment.

Adding Equal Positions

As larger commitments are added, an inverted pyramid is created (Figure 2312b) in which the risk of an immediate loss due to a small reversal becomes greater.

Adding equal numbers of contracts reduces the proportion of the original commitment in the event the trend does not materialize but increases later exposure (when, hopefully, there are large profits). The shift of risk can only be determined by the trader. With this approach, as well as the other inverted pyramid formations, the speculator should follow the rule that no unsuccessful secondary position should offset the entire profits of the prior positions.

Adding Equal Amounts

To offset the effects of disproportionate risk, subsequent positions can be added based on the new value of the market being traded. Comparing this to the previous method of equal contracts, this would reduce the number of purchases in a rising market and increase them

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in a declining market. The effect of increased volatility at higher levels would substantiate this approach to adding as a means of maintaining the same relative effect of each new position to the prior ones.

MaximumLeverage Compounding

The greatest risk and the most potential is in adding positions using all profits accumulated to date. To do this necessitates a close working arrangement with the margin department of a brokerage firm. They might even want to install a direct telephone line. Whenever possible, new positions are added, based on the assumption that profits are considered a confirmation of the trend. Being completely leveraged is a tenuous position, requiring constant monitoring of the market; there must be a welldefined stoploss at all times in anticipation of a premature reversal.

Reflecting Pyramid

One way to reduce the extreme risks of compounding is to remove positions once a specific profit level has been reached. For example, if there is a reasonable expectation of an average profit of 60 points, a reflecting pyramid (Figure 2312c) will add positions until the maximum commitment is reached at onehalf the expected profit and then reduce positions until it is entirely closed out at 60. This technique can be modified to apply to any of the methods of adding positions by requiring that the full commitment be achieved at a level below the expected profit; full liquidation may be targeted for a point above the average profit.

Comparison of Compounding Methods

Table 236 and Figures 2313a and 2313b show the risks and rewards of three methods of compounding compared with holding a single position from trade entry to exit. All forms of pyramiding increase both profits and risk. Holding an unchanged position shows consistently lower returns with a mostly higher reward/risk ratio, especially at early equity levels. Scaledown additions show an improved return and less attractive ratio; equal additions show much higher returns with a much lower reward/risk profile. The reflecting pyramid has both higher returns than the single position and an improved ratio. At onehalf the expected return, it is clearly a better choice than the other methods. As expected profits are neared, the investor must choose between the extremely high leverage and profits of adding equal positions and the excellent reward/risk ratio of the reflecting pyramid.

EQUITY CYCLES

Every system has profitloss cycles that can be seen clearly by plotting its daily or weekly equity Trending techniques show that once or twice each year, there are major increases in profits corresponding to a trending market, at other times, there is a steady decline and a stabilizing pattern to the total equity. For a system to operate as it is expected, the

positions must be kept constant. Increasing positions as equity increases in a trending cycle results in always being fully invested at the top of the cycle, when losses begin. Losses will be on a larger base than profits, and equity will drop much faster than it increased.

The same effect can occur at the bottom of an equity cycle after a nontrending market period. A sustained losing streak may cause a speculator to reduce the investment in proportion to dwindling capital. If this happens, the result will be entering into a profitable period with a smaller investment than the prior losing period. The system must have disproportionately larger profits to recover the losses and achieve a net gain. An example of a typical system is shown using a 100% gain for each profitable cycle, followed by a 50% loss cycle. Assume this cycle is repeated twice each year; in one year, the following equity pattern will occur:

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TABLE 236 Comparison of Compounding Methods*

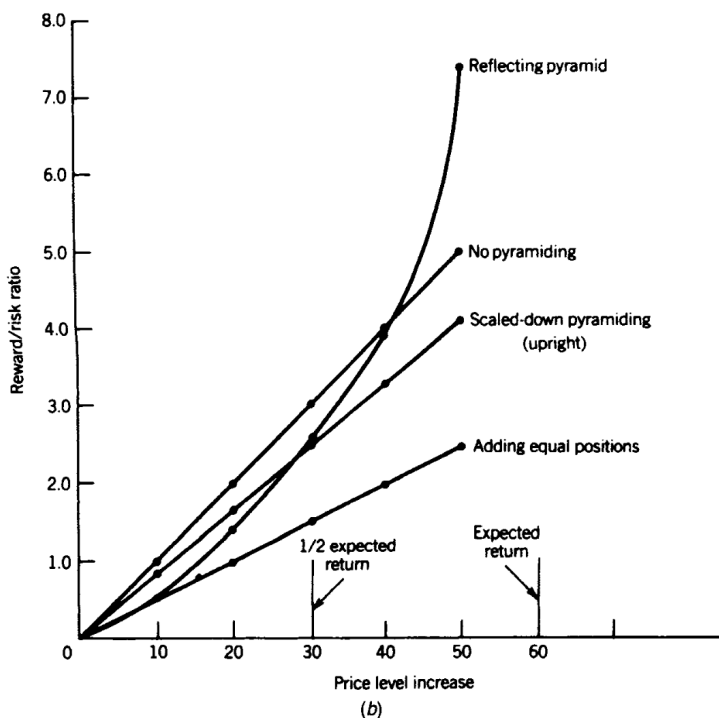
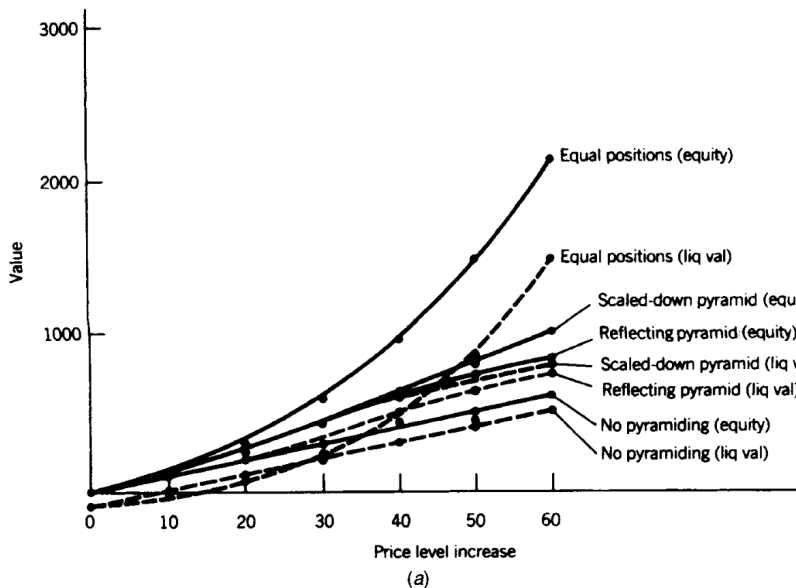
Price	Add	Total	Equity	Liq Val	Risk	Equity/Risk	Equ
<i>No Pyramiding</i>							
0	10	10	0	-100	100	0	
10	0	10	100	0	100	1.00	
20	0	10	200	100	100	2.00	
30	0	10	300	200	100	3.00	
40	0	10	400	300	100	4.00	
50	0	10	500	400	100	5.00	
60	0	10	600	500	100	6.00	
<i>Scaled-Down (Upright) Pyramid</i>							
0	32	32	0	-320	320	0	
10	16	48	320	-160	480	.67	1
20	8	56	800	240	560	1.42	2
30	4	60	1360	760	600	2.27	4
40	2	62	1960	1340	620	3.17	6
50	1	63	2580	1950	630	4.11	8
60	0	63	3210	2580			10
<i>Equal Positions</i>							
0	10	10	0	-100	100	0	
10	10	20	100	-100	200	.50	
20	10	30	300	0	300	1.00	
30	10	40	600	200	400	1.50	
40	10	50	1000	500	500	2.00	
50	10	60	1500	900	600	2.50	
60	0	60	2100	1500			
<i>Reflecting Pyramid</i>							
0	10	10	0	-100	100	0	
10	5	15	100	-50	150	.67	
20	2	17	250	80	170	1.47	
30	0	17	420	250	170	2.47	
40	-2	15	590	440	150	3.93	
50	-5	10	740	640	100	7.40	
60	-10	0	840	740			

* 1 point = \$100.

	Change in Equity	Total Equity	
Original margin		\$10,000	
Gain of 100%	+10,000	20,000	First 6 months
Loss of 50%	-5,000	15,000	
Gain of 100%	+10,000	25,000	Second 6 months
Loss of 50%	-5,000	20,000	

This leaves a net gain of 100% for the year. Each 100% profit was \$10,000. The net gain of 100% was \$5,000—the rate of return is always based on the original margin. For example, if the margin was \$10,000, the net gain would be \$5,000.

liquidated value (10point reversal). (b) Reward to risk ratio.



with the losing phase, there would be a profit of 50% for the first year and 100% for each subsequent year.

Many traders would not net 100% each year from a system that performs as the one in the example. As their profits increased, positions would be added so that at the time the total equity was worth \$20,000, the margin requirements would also be \$20,000. The 50% loss is then applied to the total equity:

	<i>Change in Equity</i>	<i>Total Equity</i>	
Original margin		\$10,000	
Gain of 100%	+10,000	20,000	} First 6 months
Loss of 50%	-10,000	10,000	
Gain of 100%	+10,000	20,000	} Second 6 months
Loss of 50%	-10,000	10,000	

Trading futures would be a great deal of effort for no return.

Holding the investment constant as shown can also be viewed by studying the growth and decline of the account excess, called the reserve. The size of the reserve relative to total equity is the key to successful management. Starting with margin and reserves equal, reserves increase during profitable periods and decrease during losing ones. Proportionately more of the total equity is traded during losing phases. This pattern can be used to improve results safely, as follows:

	<i>Change in Equity</i>	<i>Margin</i>	<i>Reserve</i>	<i>Total Equity</i>
Original investment		10,000	10,000	20,000
Gain of 100%	+10,000	10,000	20,000	30,000
Loss of 50%	-5,000	10,000	15,000	25,000
Gain of 100%	+10,000	10,000	25,000	35,000
Loss of 50%	-5,000	10,000	20,000	30,000

Using the natural equity cycles, hold the number of positions the same and allow the reserve to increase during profitable periods; maintain the same position size through the beginning of the next losing period. When the equity drop has slowed or stabilized, the total equity can be redistributed into margin and reserve according to the original 50% formula. In the next example, the total equity of \$25,000 is distributed 40% to margin and 60% to reserve at the end of the first cycle. It is redistributed so that the next profit phase will be entered with a larger base than the previous losing cycle. The result is a gradual increase in profits:

	<i>Change in Equity</i>	<i>Margin</i>	<i>Total Reserve</i>
Original investment		10,000	10,000
Gain of 100%	+10,000	10,000	20,000
Loss of 50%	-5,000	10,000	15,000
Redistribute		12,500	12,500
Gain of 100%	+10,000	12,500	25,000
Loss of 50%	-5,000	12,500	18,750
Redistribute		15,625	15,625

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Trading on Equity Cycles

If a moving average technique is traded, the equity resulting from this strategy will fluctuate with the trending nature of the market. By applying a moving average analysis to the equity itself, the trending and nontrending periods are identified by buy and sell signals just as though the equity series was a price series.

An equity buy means that the market has begun trending; the length of this period depends on the calculation period of the trend. A sell signal means that the market is no longer trending. These signals can be taken as "buy the system" or "Short the system"; that is, enter all positions that the system currently holds or liquidate the entire portfolio and hold cash. An equity buy could also be taken as the point to redistribute the equity into the original ratio of margin to reserves. If the normal profile of price movement is to spend a large proportion in a sideways pattern, then there should be sustained periods of downward equity trends., trading equity cycles can improve performance.

INVESTING AND REINVESTING: OPTIMAL f

Optimal f is the optimal fixed fraction of an account that should be invested at any one time, or the size of the bet to place on any one trade. The amount to be risked is measured as a percentage of the portfolio size. The objective is to maximize the amount invested (put at risk), yet avoid the possibility of total loss. Trading a very small part of assets can be a poor use of capital, while trading too much guarantees bankruptcy or ruin. Optimal f is the ideal portion of an investment that should be placed at risk at any one time. If you risk less than the optimal f then you are not generating the peak profits; however, if you trade more than optimal f you assure eventual ruin.

Investing generally has a twolevel optimal f the part of the total portfolio put at risk compared with that part held in cash equivalents, and the individual size of the commitment to each stock or futures market within that portfolio. This is particularly important for futures, where the high leverage of individual markets makes it very easy to risk too much on

each trade.

Fixed Initial Investments

Then, how much should be invested? The optimal amount is difficult to pinpoint because you would have to know what risks lie ahead, and of course, that's not possible. However, based on a very small likelihood of losing 50% of the portfolio when 50% is invested, one might say that a portion under a 50% investment is best. To account for greater uncertainties in the future, you could increase your confidence by investing only 25% of the initial portfolio. This approach has negative effects, because a smaller relative investment reduces both risk and returns. When the investment becomes too small, the returns are no longer attractive.

The chance of a catastrophic risk is an important concern for any investor or portfolio manager. For practical purposes this is always figured on the historic profile of the data or trading results. This still leaves uncertainty in the final values. Nevertheless, the most extreme situation is often found by using the calculation for risk of ruin (in a previous section of this chapter), most often applied to gambling situations in which the bet sizes, pay out, and odds are well defined. When there are enough test data and trades, this technique has been applied to trading systems (see the section "Wins Not Equal to Losses").

Some analysts have tried to deal with the uncertainties of price movements by using a Monte Carlo technique in testing, which shifts the sequence of blocks of data, or profit and loss results, so that they occur in random order. The worst results are considered the greatest risk. This approach may be unrealistically severe, yet even the real performance is not likely to reflect the size of the risk in the future. For those traders applying a longterm

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trendfollowing technique to capture moves that are based on economic or government policy, sustained profits are most often followed by a reversal before the trade is ended. In fact, the ending change of direction is directly related to the sustained move. To move this data around so that the loss comes at a different time may create a large loss without the offsetting profit, which is a situation that is unfair to the trading strategy. Before applying a Monte Carlo analysis, it is first necessary to identify the dominant period of sequential correlation to avoid segmenting the series incorrectly.

For an initial investment, the optimal f is simply the maximum part of that portfolio that can safely be traded without any significant risk of ruin. For those investors who take out profits when they occur and continue to trade based on the same assumed initial investment, nothing need be changed unless exceptionally high risk causes a reassessment and decrease in the amount of leverage. However, it is more common and more complicated for the investor to vary the amount committed to the market by either increasing or decreasing leverage. This involves (1) determining the right time to change the leverage, (2) calculating the amount to increase the investment when there are profits, and (3) figuring the size of the reduction when there are losses exceeding some designated amount. These are issues

that are addressed by optimal f

Finding Optimal f

Ralph Vince, in his popular book, *Portfolio Management Formulas*,¹¹ focuses on optimal f, risk of ruin, and other practical items. Optimal f is the ideal amount of an investment that should be put at risk at any one time. As background for this, we need to formulate the relationship where the percentage gain needed to recover a loss is larger than the percentage lost.

$$\text{Required gain} = \frac{1}{1 - \text{percent loss}} - 1$$

That is, a 50% loss requires a 100% gain to restore the original value. Because the amount risked on each trade depends on our expectations of loss, the results obtained from the optimal f calculation will be the size of the bet, invested amount, or the number of contracts to be traded, as a percentage of the maximum loss. As we already know, the value used as a maximum loss will be an estimate, because losses can always be greater than only those experienced in the market, whether theoretical or real. In addition, the optimal f will be different for each system, depending upon its performance profile.

The mathematics needed to determine optimal f is based on the Kelly Betting System. Kelly states that the optimum bet is the one that maximizes the growth function $G(f)$:

$$G(f) = P * \ln(1 + B * f) + (1 - P) * \ln(1 - f)$$

where f is the optimum fixed fraction

P is the probability of a winning bet or trade

B is the ratio of the average winning return to the average losing return

$\ln$ is the natural log function

The solution for finding the optimal fixed fraction to invest uses the geometric product and geometric mean, which represent the way in which profits and losses accrue.

$$\text{Optimal } f = \max \left(\prod_{i=1}^N \left(1 + \frac{f \times (-PL_i)}{\text{largest loss}} \right) \right)^{1/N}, \quad \text{for } f = .01 \text{ to } 1.0$$

¹¹ Ralph Vince, *Portfolio Management Formulas* (John Wiley & Sons, 1990, pp. 7086).

⁹ John L. Kelly, Jr., "Kelly Betting System" *Bell System Technical Journal* (July 1956).

where max is the function that selects the maximum value

$\prod$ is the product (this symbol is 2 vert + 1 across the top (as in equation above))

largest loss is the largest loss of any PL_i

PL_i is the profit or loss for trade i

N is the number of trades

By testing values off between .01 and 1.0, and finding the geometric

mean of all trades (each percentage profit or loss applied to the account value before the current trade), we find the value f that gives the best return. That f value is the optimal f , the amount of the total account that should be invested for each trade.

A simpler way of expressing optimal f , the amount invested on a single trade, is given as¹

$$f = [p \times (R + 1) - 1] / R$$

where R = the ratio of average profit to average loss

p = the probability of a winning trade

Therefore, if $p = .50$, there is an equal chance of a profit or a loss, and the average profit is \$400 while the average loss is \$200 (giving $R = 2.0$), then $f = (.50(2 + 1) - 1) / 2 = .5 / 2 = .25$ or 25% of the available capital. Given an equal chance of a profit or a loss, it is not likely that there would be four losses in a row, each of 25%; however, the theory of runs shows that, out of every 100 trades, there should be one run of six. Eventually, there will be a run of four or five losses in a row. Optimal f however, invests a fraction of the current equity; therefore, after a loss of 25%, the next investment is 25% of the balance, or 18.75% of the initial equity. If there are further losses, that amount drops to 14.06%. After three losses in a row, instead of having lost 75% of the initial equity, the investment has only dropped by 57.81%. Over time, with profits twice as large as losses, and winning trades normally alternating with losing trades, the losses will be recovered.

Observations of Optimal f

According to Alex Elder,² there are some difficulties in using optimal f . Because the value is based on every historic trade, the ideal amount to invest on the next trade will keep changing. In addition, if you trade a position larger than the optimal f , with average results, you can expect to go broke eventually because you are overinvesting. On the other hand, if you invest less than the optimal amount, then your risk decreases arithmetically, but your profits decrease geometrically, which is another bad scenario. Because this process can become very complicated, the simple solution for most investors is to keep trading the same amount, leaving a large reserve so you are not caught short.

On the positive side, Dr. Elder concludes that the most useful results of optimal f is that it shows the important principles:

1. Never average down.
2. Never meet margin calls.
3. Liquidate your worst position first.

Practically Speaking

Evaluating the risk and reward of a trading program, even using a number of years of actual performance, rarely gives results that are statistically accurate. Markets change and the performance profile of any trading system can vary significantly over long time periods. Determining the amount to invest on a single trade based on the average risk and average return

Robert P Rotella, *The Elements of Successful Trading* (The New York Institute of Finance, 1992, pp. 549550).

21 Dr. Alexander Elder, *Trading for a Living* (John Wiley & Sons, 1993).

of past performance can lead to a tragic end. When investing 25% in each trade, a loss that is twice what is expected, followed by a smaller profit and another large loss (in a more volatile period), could exhaust your capital, regardless of the statistics.

in general, the less you risk, the safer you are. From time to time there are price shocks that produce profits and losses far greater than the averages show. Although the theory of an optimal fixed fraction may be correct, the numbers used in the calculation are not often reliable.

COMPARING EXPECTED AND ACTUAL RESULTS

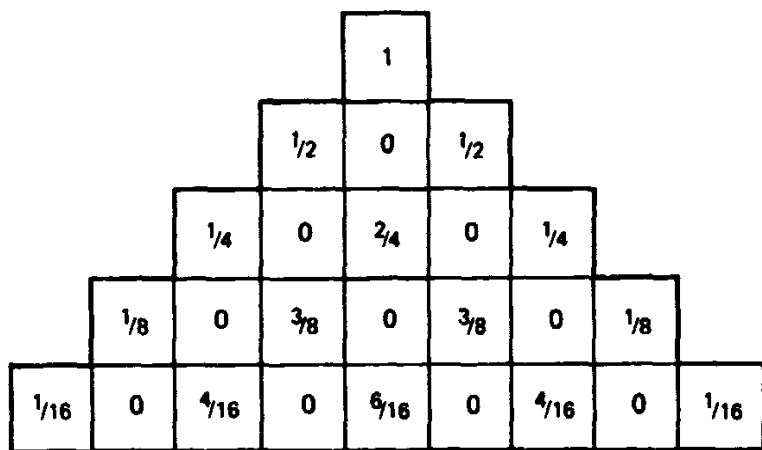
in the development of an economic model or trading system, the final selection is usually the result of a performance comparison of the completed models. Often the results are given in terms of profit/loss ratios, annualized percentage profits, expected reliability (percentage of profitable trades to total trades), and potential risk. Although these statistics are common, their predictive qualities and sometimes their accuracy are not known. On occasion, these results are generated by a sample that is too small, and usually they are not the results of a predictive but an historic test. This does not mean that the model will be unsuccessful, but that the pattern of success might vary far from the expected profit/loss ratio, reliability, and risk. In actual trading, every speculator experiences a series of losses far exceeding anything that was expected; at that point, it is best to know whether this situation could occur within the realm of the system's profile or whether the system has failed. For example, a moving average system is expected to have 1 out of 3 profitable trades with a profit/loss ratio of 4: 1. But the first 10 trades of the system are losers. Should trading be stopped?

Binomial Probability

Consider the application of a random-number sequence to the probability of l losses in n tries when the probability of a loss is $1/2$. This area of probability is credited to Bernoulli, who developed the *Bernoulli process*. A clear representation of a random walk is shown in Figure 23-14, where each box represents the probability of being at a specific time in a forward random walk. The resulting probability distribution is called the *binomial distribution*.

The forward random walk has an analogy to Pascal's triangle showing the probability of a continuous random walk. The sequence $1/2, 1/4, 1/8, \dots, (1/2)^n$ is the Theory of Runs. The probability of successive losses of a run of the same length, $(1/2)^{n+2}$.

FIGURE 23-14 Pascal's triangle.



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A binomial distribution is useful in considering the total number of losses that can occur in any order within a sequence of trades; it is the probability of getting to a specific point at the base of Pascal's triangle when there is a high probability of moving to the left (losses) rather than the right (profits). The formula for the binomial probability is:

$$B(l;p,n) = \frac{n!}{l!(n-l)!} p^l (1-p)^{n-l}$$

where 1 is the number of losses

n is the total number of tries

p is the probability of a loss

and the symbol "!" is the factorial (e.g., $5! = 5 \times 4 \times 3 \times 2 \times 1$).

Consider the first 15 trades of a system with a Probability of success of 1/3. How many losses should be expected? To answer the question, find the binomial probability B for all possibilities and form a distribution function. Let $l = 4$. Then,

$$\begin{aligned} B(4; .667, 5) &= \frac{5!}{4!1!} (.667)^4 (.333)^1 \\ &= \frac{120}{24} \times (.19792) (.333) \\ &= 5 \times .0659 = .32954 \end{aligned}$$

The binomial probability of having 4 losses out of the first 5 trades is about 33%. The following table shows the probability of losses for the first 5, 10, and 15 trades of a system, with a 1/3 predicted reliability. Results show the highest probability of occurrence of loss is at the % point (mean) for each sequence, but the standard deviation gives the range of variance about the mean, so that from 2.3 to 4.4, losses are expected in every 5 trades, 5.2 to 8.2 in 10 trades, and 8.2 to 11.8 losses in 15 trades (Table 237).

Note that in the 5-trade example, the chances of no losses is only 1%, and there is a 13% chance of all losses. For the purpose of evaluation, it is easier to look at the maximum rather than the minimum number of losses. For 15 trades, there is an 8% chance of 13 or more losses; if the system has produced more than 12 losses in that period, there is something wrong with the predicted reliability.

In addition to the Pascal distribution, the reader may find the Poisson and various skewed distribution functions have application to system evaluation.

χ^2 —Chi-Square Test

Once a system has been traded and there is enough significance between these actual results and the expected results, the *chi-square test*. First, there must be enough data for sampling, the formula for error is $1/\sqrt{N}$, where N is the number of trades. If there are 25 trades, the expected error in the calculation is 2%, and the results are accurate to 10%.

Assume that the real trading results show a reliability of 35%. What are the chances of passing the *chi-square test* is

$$\chi^2 = \frac{(O - E)^2}{E}$$

where O is the observed, or actual result, and E is the expected result.

5 Trades		10 Trades		
Losses	Probability (%)	Losses	Probability (%)	Losses
0	1	0	0	0
1	4	1	0	1
2	16	2	0	2
3	33	3	2	3
4	33	4	5	4
5	13	5	14	5
		6	23	6
		7	26	7
		8	19	8
		9	9	9
		10	2	10
				11
				12
				13
				14
				15
$m^* = 3\frac{1}{2}$		$m = 6\frac{2}{3}$		
$sd^\dagger = 1.05$		$sd = 1.5$		

* Mean.

† Standard deviation.

$$\begin{aligned}
 \chi^2 &= \frac{(20 - 35)^2}{35} + \frac{(80 - 65)^2}{65} \\
 &= \frac{(-15)^2}{35} + \frac{(-15)^2}{65} \\
 &= \frac{225}{35} + \frac{225}{65} = 6.428 + 3.46 \\
 &= 9.89
 \end{aligned}$$

The percentage of actual winning trades is compared with the anticipated winning trades and the losing trades with the expected losing trades. The answer must be found in the first row of Table 238, which gives the distribution of X' .

The probability is distributed unequally in the table because the results are only significant if the probability is small, showing less likelihood of the results occurring by chance. For this simple twoelement test, the result P is classified as

Highly significant if $P \geq 10.83$ (.1% or 1/1,000)

Significant: if $P \geq 6.64$ (1% or 1/100)

Probably significant if $P \geq 3.84$ (5% or 1/20)

The answer $X' = 9.89$ is between . 1% and 1% showing significance. For a large sample, the actual reliability should not have been 20% when 35% was expected.

The chisquare test can be used to compare actual price movement with random patterns to see whether there is appreciable variation. In the section on the Theory of Runs, Table 239 showed:

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TABLE239 Results from Analysis of Runs

Cases Less 1	Probability of Occurring by Chance					
	.70	.50	.30	.20	.10	.05
1	.15	.46	1.07	1.64	2.71	3.84
2	.71	1.39	2.41	3.22	4.61	5.99
3	1.42	2.37	3.67	4.64	6.25	7.82
4	2.20	3.36	4.88	5.99	7.78	9.49
5	3.00	4.35	6.06	7.29	9.24	11.07
6	3.83	5.35	7.23	8.56	10.65	12.59
7	4.67	6.35	8.38	9.80	12.02	14.07
8	5.53	7.34	9.52	11.03	13.36	15.51
9	6.39	8.34	10.66	12.24	14.68	16.92
10	7.27	9.34	11.78	13.44	15.99	18.31

TABLE 23-8 Distribution of χ^2

<i>Length of Run</i>	<i>Expected Results (E)</i>	<i>Actual Results (O)</i>
1	1225	1214
2	612	620
3	306	311
4	153	167
5	77	67
6	38	41
7	19	16
8	10	5
9	5	3
≥10	4	5
≥ 8*	19	13

* The last groups were combined in order not to distort the results based on a small sample.

Applying the actual data for runs of one through eight against a random distribution,

$$\begin{aligned}
 \chi^2 &= \sum_{n=1}^8 \frac{(O_n - E_n)^2}{E_n} \\
 &= \frac{(1214 - 1225)^2}{1225} + \frac{(620 - 612)^2}{612} + \frac{(311 - 306)^2}{306} + \frac{(167 - 153)^2}{153} \\
 &\quad + \frac{(67 - 77)^2}{77} + \frac{(41 - 38)^2}{38} + \frac{(16 - 19)^2}{19} + \frac{(13 - 19)^2}{19} \\
 &\quad \begin{matrix} (1) & (2) & (3) & (4) & (5) \\ = .09877 + .10457 + .08169 + 1.2810 + 1.2987 \\ & (6) & (7) & (8) \\ & .23684 + .47368 + 1.8947 \\ & = 5.470 \end{matrix}
 \end{aligned}$$

are not significant; the Theory of Runs shows that all cases taken together give the same patterns as chance movement. Individual runs or sets of two or three adjacent runs can be inspected for distortion. In both cases, the results are further from normal but not mathematically significant. The two runs that differed the most were 4 to 5 days, which showed an 11% probability of occurring by chance.

Highly significant price runs can be found in the occurrence of extended runs, for example, 20 days, which is experienced occasionally in trending markets. By looking at the asymmetry of price movement, where a reverse run of 1 day is of negligible value, the significance of these runs will dramatically increase. Price movement is not a simple matter of random runs and equal payout.